CR-112245

ACTIVE TRANSMISSION ISOLATION/ROTOR LOADS MEASUREMENT SYSTEM

FINAL REPORT

by Irwin J. Kenigsberg, John J. DeFelice

Sikorsky Report No. SER-50821

March 1, 1973

Prepared Under Contract No. NAS1-11549 by
Sikorsky Aircraft Division of United Aircraft Corporation
Stratford, Connecticut

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AND
UNITED STATES ARMY

NASA CR-112245

ACTIVE TRANSMISSION ISOLATION/ROTOR LOADS MEASUREMENT SYSTEM*

by Irwin J. Kenigsberg
John J. DeFelice

Prepared Under Contract No. NAS1-11549 by

SIKORSKY AIRCRAFT DIVISION OF UNITED AIRCRAFT CORPORATION

Stratford, Connecticut

for NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AND
UNITED STATES ARMY

* "The contract research effort which lead to the results in this report was financially supported by USAAMRDL (Langley Directorate)"

TABLE OF CONTENTS

LISTING OF SYMBOLS

W_{UB1}	-	Weight of the upper part of the upper body.
X_{UB1}	-	x-location of the C.G. of the upper part of the upper body.
Y_{UB1}	-	y-location of the C.G. of the upper part of the upper body.
Z_{UB1}	-	z-location of the C.G. of the upper part of the upper body.
I_{OXUB1}	-	Moment of Inertia about the x-axis of the upper part of the upper body.
I_{OYUB1}	-	Moment of Inertia about the y-axis of the upper part of the upper body.
W_{UB2}	-	Weight of the lower part of the upper body.
X_{UB2}	-	x-location of the C.G. of the lower part of the upper body.
Y_{UB2}	-	y-location of the C.G. of the lower part of the upper body.
Z_{UB2}	-	z-location of the C.G. of the lower part of the upper body.
I_{OXUB2}	-	Moment of Inertia about the x-axis of the lower part of the upper body.
I_{OYUB2}	-	Moment of Inertia about the y-axis of the lower part of the upper body.
W_{LB}	-	Weight of the lower body.
X_{LB}	-	x-location of the C.G. of the lower body.
Y_{LB}	-	y-location of the C.G. of the lower body.
Z_{LB}	-	z-location of the C.G. of the lower body.
I_{OXLB}	-	Moment of Inertia about the x-axis of the lower body.
I_{OYLB}	-	Moment of Inertia about the y-axis of the lower body.
X_{Ii}	-	x-location of the active isolator (i).
Y_{Ii}	-	y-location of the active isolator (i).
Z_{Ii}	-	z-location of the active isolator (i).

X_{LCi}	-	x-location of the drag strut mounting point on the transmission frame.
Y_{LCi}	-	y-location of the drag strut mounting point on the transmission frame.
Z_{LCi}	-	z-location of the drag strut mounting point on the transmission frame.
X_{TAPi}	-	x-location of the torque application point on the transmission frame.
Y_{TAPi}	-	y-location of the torque application point on the transmission frame.
Z_{TAPi}	-	z-location of the torque application point on the transmission frame.
ALPHA	-	The angle the torque application strut makes with the lateral centerline.
X_P	-	x-location of the point where the propulsive load is applied.
Y_P	-	y-location of the point where the propulsive load is applied.
Z_P	-	z-location of the point where the propulsive load is applied.
BETA	-	The angle the propulsive loading cable makes with the longitudinal centerline.
X_A	-	x-location of the reference point A located at the rotor head.
Y_A	-	y-location of the reference point A located at the rotor head.
Z_A	-	z-location of the reference point A located at the rotor head.
A_H	-	Air volume reaction surface - high pressure side.
A_L	-	Air volume reaction surface - low pressure side.
P_A	-	Isolator air precharge - high side.
P_B	-	Isolator air precharge - low side.

LISTING OF SYMBOLS (continued)

G	-	Isolator high gain.
Cv	-	Isolator element viscous damping coefficient.
XAi	-	x-location of accelerometer (i).
YAi	-	y-location of accelerometer (i).
ZAi	-	z-location of accelerometer (i).
SF	-	vibratory force applied with the hydraulic shaker.
SFREQ	-	frequency at which the shaker force is applied.
XSH	-	x-location of the hydraulic shaker.
YSH	-	y-location of the hydraulic shaker.
ZSH	-	z-location of the hydraulic shaker.
THTLAT	-	The angle between the shaker force and the Z axis in the Y-Z plane.
THTLON	-	The angle between the shaker force and the Z axis in the X-Z plane.
DR	-	propulsive load.
TAP1	-	Load in torque application system load cell located on the port side of the aircraft.
TAP2	-	Load in torque application system load cell located on the starboard side of the aircraft.
FLC1T	-	Load in front longitudinal drag link.
FLC2T	-	Load in front lateral drag link.
FLC3T	-	Load in rear longitudinal drag link.
FLC4T	-	Load in rear lateral drag link.
PiH	-	High side operating pressure of isolator (i).
PiL	-	Low side operating pressure of isolator (i).

LISTING OF SYMBOLS (continued)

DELi	-	Relative displacement of isolator (i).
ACCi	-	Steady and vibratory acceleration plus the phase angle measured in accelerometer (i).
Ba,b	-	A damping coefficient on low and high pressure sides of isolator element.
Ga,b	-	Servovalve flow gains for low and high pressure sides of isolator element.
Pd	-	Isolator element drain pressure.
Ph,l	-	Precharge pressure of isolator element, high and low pressure source.
qa,b	-	Flow rates of servovalve for low and high pressure sides of isolator element.
Sa,b	-	Piston area for low and high pressure sides of isolator element.
Vcao,bo	-	Volume contained between diaphrams and air restriction for low and high pressure sides of isolator element.
Vca',b'	-	Volume contained between diaphrams and air restrictor for low and high pressure sides of isolator element under operating conditions.
Vt	-	Volume contained between housing and air restrictor for general air spring.
Vta,b	-	Volume contained above air restrictor for low and high operating pressure sides of isolator element.
S	-	Steady value.
V	-	Vibratory value.
P	-	Phase angle referenced against the contactor of the hydraulic shaker.

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

LIST OF TABLES

SUMMARY

Modifications were incorporated into the Sikorsky active transmission isolation system to provide the capability of utilizing the system as a rotor force measuring device. These included; isolator redesign to improve operation and minimize friction, installation of pressure transducers in each isolator and load cells in series with each torque restraint link. Full scale vibration tests performed during this study on a CH-53A helicopter airframe verified that these modifications do not degrade the systems wide band isolation characteristics.

Bench tests performed on each isolator unit indicated that steady and transient loads can be measured to within 1 percent of applied load. Individual isolator vibratory load measurement accuracy was determined to be 4 percent. Load measurement accuracy was found to be independent of variations in all basic isolator operating characteristics.

Full scale system load calibration tests on the CH-53A airframe established the feasibility of simultaneously providing wide band vibration isolation and accurate measurement of rotor loads. Principal rotor loads (lift, propulsive force, and torque) were measured to within 2 percent of applied load. This is within the accuracy projected for this system during the predesign study of the Rotor Systems Research Aircraft (Ref. 1). The time histories of transient loads were accurately determined while relative motions at the transmission airframe interface were maintained within design tolerances of control systems and high speed engine drive shafts.

In addition to the measurement of principal rotor forces, tests were performed to establish the feasibility of measuring vibratory rotor forces. It was determined that vibratory forces could be measured with an average error of 20 percent of applied force at all frequencies where effective isolation was provided. The higher error in vibratory load measurement results from the requirement to adjust measured load cell and isolator loads to include the inertia forces resulting from transmission motion. The principal contributor to the increased error was found to be the sensitivity of the accelerometers utilized in the tests. Evaluation of piezoelectric accelerometers is therefore recommended for improved accuracy in future force measurement tests. It is anticipated that through the use of the piezoelectric accelerometers, the accuracy of vibratory load measurement can be substantially improved.

As a result of these tests it is concluded that it is feasible to use a rotor force measurement system in determining steady, transient and vibratory rotor loads while providing tunable transmission isolation. It is recommended that the active transmission isolation system be further developed for vibration control and rotor force measurement in conjunction with slowed rotor operation.

Page Intentionally Left Blank

INTRODUCTION

A basic requirement of the proposed Rotor System Research Aircraft (RSRA) is an in flight rotor force measurement system (Ref. 1). In addition, if the RSRA is to accomodate certain rotors which operate over a wide range of blade passage frequencies, such as the slowed rotor, an active vibration suppression system is required to avoid rotor/airframe dynamic resonances. A system of this type would also provide tuning for other rotors whose excitation frequencies fall beyond the operational bands made available through structural tuning of the airframe.

Full scale active transmission isolation has been successfully demonstrated under USAAMRDL Contract DAAJ02-69-C-0101 (Ref. 2). The isolation system installed on a CH-53A helicopter consists of three unidirectional hydropneumatic isolators installed vertically at the transmission/airframe interface and horizontal rigid links connecting the transmission to the airframe to provide torsional restraint. The system exhibits wide band vibration isolation at all frequencies above isolator resonances while limiting steady and transient relative airframe/transmission deflections within design targets for control systems and high speed engine drive shafts.

Load calibration tests of an individual active isolator performed under NASA Contract NAS1-10850 established the feasibility of utilizing the units as load measuring devices.

The objective of this study is to establish, through full scale experimental ground tests, the feasibility of providing simultaneous wide band active transmission isolation and accurate measurement of steady, transient and vibratory rotor loads.

Page Intentionally Left Blank

ISOLATOR MODIFICATIONS

The active isolators as described in Reference 2, were modified and reworked to remove wear resulting from previous operation and to improve their accuracy as load measurement devices. Features of the isolator units are illustrated in Figures 1 and 2. Figure 3 shows the isolator modifications. That is, the existing sleeves were replaced and the piston head was turned down and replaced with a self-aligning Beryllium-copper head to reduce friction. A tight press-fit stainless steel cylindrical sleeve and a ball bushing were installed to eliminate the potential of the piston shaft cocking. The piston shaft was built up through chrome plating and ground to eliminate slop. In addition, a stainless steel stop and concentric Beryllium-copper self-aligning seal was installed at the base of the piston shaft. Spacers were installed between the sleeve and caps to eliminate cocking, caused by torquing the head bolts. Hydraulic pressure transducers were installed and the anti-rotation device in the servo-linkage was modified to prevent binding during operation.

ISOLATOR BENCH TESTING

The modified active isolators underwent load calibration and functional bench testing prior to installation on the test vehicle for the full scale system calibration. Steady, vibratory and transient loads were applied to each isolator. Effects of variation in isolator precharge, gain, and damping were performed to evaluate the effect of said parameters on load calibration.

Prior to installation in the bench test rig, dry breakout friction was evaluated on each isolator. All three isolators exhibited breakout friction of under 7 pounds over the limits of piston travel, as is illustrated in Figure 4. These checks were made during each stage of assembly, to identify whether misalignment existed, and also at the conclusion of final assembly. The tests were repeated under hydraulic pressure in the bench test rig. No change in breakout friction was identified.

Isolator testing was performed in the bench test facility shown in Figure 5. Mounted in series with the instrumented isolator unit was a hydraulic ram used for applying steady and vibratory loads and a load cell used to measure the applied load.

Instrumentation, shown in Figure 6, consisted of two absolute pressure transducers, a displacement potentiometer for monitoring isolator operation, pressure monitoring gages, and three load cells to establish the applied load. Load cells of 5, 10, and 20 thousand pounds were utilized to minimize the applied load error in each test range. Oscillograph traces were utilized to record direct measurement of applied load, isolator pressures and displacement. In addition, two traces were utilized to record the isolator load and error which are electronically calculated from direct measurements by a specially constructed analog circuit.

Basic testing consisted of steady load calibrations including an evaluation of the effects of vibratory load levels which can be anticipated in the in-flight environment. The vibratory loading utilized, was a maximum of ±1000 lbs at sample frequencies of 10, 18.5 and 25 HZ. Transient load tests (15,000 to 2,000 lbs in 2 seconds) were also conducted. The tests were then expanded to evaluate the effect of variations in isolator gain, precharge and damping on the load measurement accuracy. The parametric variations tested are listed in Table 1.

The results obtained from these tests are summarized below:

1. With the isolator at its nominal settings, steady loads were measured to within ±1% of the applied load about a linear bias which can be removed through calibration. The presence of vibratory load at frequencies of 10, 18.5 and 25 HZ,did not affect the accuracy of measuring steady loads (Figure 7). In addition, all transient test points, fall within the established steady error band (Figure 8).

2. All three active isolators exhibit identical measurement accuracy (Figures 7, 9, and 10).

3. Vibratory loads can be measured to within ±4% of applied vibratory load, independent of steady load applied or excitation frequency. (Figures 11 to 13 illustrate these results).

4. Isolator load measurement accuracy is independent of variations in isolator characteristics. Ten combinations of gain, precharge and damping were considered. The resulting steady and vibratory calibration data is presented in Figures 14 to 21. It is concluded from these tests, that parametric variations of isolator parameters need not be performed during the full scale system test since no effect on load measurement accuracy is detected.

FULL SCALE TEST DESCRIPTION

Test Apparatus and Loading Systems

The ground test facility used to evaluate the active isolation system as a rotor loads measurement system is shown in Figure 22. Principal elements are a bungee suspension system to simulate free flight, three load application systems, for application of steady and transient rotor loads, and a hydraulic shaker mounted at the rotor head to simulate steady-state vibratory rotor loads.

The structural static CH-53A test vehicle, configured with a MK II tail rotor pylon and stabilizer, was weighed and ballasted to a 34,200 pound gross weight with a neutral center-of-gravity mass distribution. Concentrated weights were used to dynamically simulate the tail rotor and intermediate gearbox, which were not installed on the test vehicle. The engines were not installed or simulated to simplify the test set-up.

The bungee suspension system labeled in Figure 23 lifted the entire vehicle off the deck to simulate free flight by maintaining all rigid body modes below 1 HZ. A rigid ballast (shown in Figure 23) was used to simulate the mass of the rotor head and blades and to provide attachments to the suspension system, the external longitudinal loading system, and the shaker. The transmission was bolted to a large steel plate, with the isolators suspending the fuselage through holes cut in the skin of the cabin ceiling (Figure 24). The lower isolator attachment was an I-beam frame, weighing approximately 700 pounds, bolted to the lower caps of the fuselage frame (Figure 25). The weight of the transmission attachment plate, approximately 1300 pounds, was offset by using a transmission housing without gears. This permitted the upper body to have a mass moment of inertia and center-of-gravity simulating that of the actual vehicle. System installation was largely dictated by the location of the existing CH-53A test vehicle structural members. It must be emphasized that the weight and complexity of this installation would not exist if the isolation system were integrated into the vehicle's basic design. In-plane and torque restraint was provided at the transmission base by four drag struts located symmetrically about station 342 and the fuselage centerline (Figure 24).

A complete assembly of the test facility is illustrated in Figure 26. Simulated steady and transient propulsive force was applied to the rotor head with a loading system comprised of a hydraulic cylinder, a 5000 pound BLH load cell, an electronic quick release mechanism, and a steel cable attached, in series between the rotor head and the aircraft tail structure (Figure 27). Loading was applied to the rotor head by pressurizing the cylinder, thus producing tension in the cable between the rotor head and the tail structure. Transient loading was accomplished by activating the quick release mechanism which released the applied load instantaneously, applying a step-input load to the rotor head.

Apparatus and Loading Systems (continued)

Steady main rotor torque loading was provided through a pair of hydraulic cylinders located so as to apply a couple to the main rotor gearbox. The cylinders shown in Figures 24 and 28 attached to the transmission adapter plate and to a specially designed steel framework, which in turn was fastened to the basic airframe. Applied loads were measured with 20,000 pound BLH load cells, located in series with the cylinders. The applied torque was reacted by the four in-plane links (Figures 24 and 28). The links, of equal length, were located symmetrically about station 342 and the fuselage centerline and attached between the transmission plate and the steel loading framework. Torque loads were measured with four 20,000 pound BLH load cells, one located in series with each link. Design of this apparatus provided for location and installation of the torque cylinders, drag links, and steel framework at the base of the transmission so as not to alter the capability of the system to isolate the aircraft from vertical and in-plane vibratory excitations. Spherical bearings were incorporated at each attachment point to allow movement of the upper body with respect to the basic airframe during isolation tests.

The vertical transient loading system shown in Figures 25 and 29 consisted of a hydraulic cylinder attached to the base of the transmission and an electronic quick release mechanism fastened to a steel framework which in turn bolted to the isolator lower attachment frame. A 10,000 pound BLH load cell, in series with the cylinder, measured the applied load. Loading was accomplished by pressurizing the cylinder which pulled the transmission toward the fuselage. Transients were accomplished by activating the quick release mechanism which instantaneously released the applied load, providing a step-input load to the upper body. Steady lift variations were also accomplished using this system.

Steady-state vibratory loadings were simulated with a hydraulically driven unidirectional shaker. The shaker consisted of two counter-rotating eccentric masses with adjustable unbalance which produced a unidirectional sinusoidal excitation proportional to the square of the rotational speed. The shaker was hydraulically powered with a large commercial pump. A manually operated flow bypass control valve was used to adjust rotational speed. The shaker axis was reoriented to provide vertical, longitudinal, and lateral excitations and combinations thereof.

Test Instrumentation

Four measurement systems were used to meet the requirements of these tests. The first system, involving a normalizing unit and an x-y-y' plotter output display, defined the frequency response of the test vehicle with and without the isolators activated. Steady and vibratory load measurement data was acquired, utilizing the Dymec Load Measurement System and a 36 channel CEC oscillograph. A narrow-band FM tape system was used to record the transient response real-time histories of the load measurement parameters for transient load conditions. The FM tape system was also used as a back-up for measuring vibratory load conditions. The major instrumentation components and master test control panel are shown in Figure 30. Active isolators were instrumented in the same manner as in the load calibration bench tests. Accelerometer locations and their orientation with respect to the test vehicle are illustrated by arrows in the structural arrangement shown in Figure 31. Two sets of accelerometers were utilized, each set located at the individual upper and lower center of gravity of the simulated transmission and rotor head. This instrumentation configuration was selected so as to preclude any errors resulting from relative motion due to flexibility in the shaft. The response of the transmission and simulated rotor head, combined with the measured vibratory load in the isolators and torque restraint links, provide the necessary measurement of vibratory forces.

VIBRATION ISOLATION SUBSTANTIATION

The ability of the active isolation system to provide wide-band vibration isolation has been demonstrated by the tests described in Reference 2. The purpose of these tests was to verify that modifications required for load measurement did not alter these characteristics.

The steady-state isolator evaluation was made by comparing frequency response sweeps from the isolated and hard-mounted test vehicle configurations. Sweeps in all three principal directions were conducted from 150 to 1800 CPM (2.5 HZ to 30 HZ) with a main rotor unidirectional excitation of 850 pounds achieved at the CH-53A 6P frequency (1110 cpm).

Due to modifications in the individual units and the overall test vehicle configuration, including ballast distribution, system operating pressures were found to vary from previous test data. In order to maintain the spring rate of 10,000 pounds per inch as specified in Reference 2, air precharge pressures were modified as required. The precharge pressure calculations for each unit are presented in Appendix I.

Isolation Substantiation

The result of selected isolated and unisolated response sweeps are presented in Figures 32 to 43. These sweeps show a substantial reduction of fuselage response due to main rotor excitations in all three principal directions, thus substantiating that the modifications required for the load calibration tests, have not altered the systems isolation characteristics. Effective isolation in the inplane directions was obtained from an effective 3P through the highest frequency tested (555 CPM to 1800 CPM), while the isolation present in the vertical direction exists over a slightly narrower band. The isolation system under discussion, was designed specifically for the CH-53A Helicopter, with an articulated rotor system. Experience with five and six bladed rotors of this type indicate that the principal vibratory excitations are in the inplane direction. Therefore, primary consideration in the design (Reference 2) was given to optimizing isolation for these excitations. The inplane isolator modes at 300 CPM were located as low as possible to obtain maximum 6P isolation, while minimizing 1P amplification. In the original design of this installation the vertical isolator mode at 650 CPM, was constrained by the location of the inplane modes and the geometry of the system. As a result, vertical isolation was not optimized at lower frequencies. Since some degree of isolation existed throughout the desired frequency range, no attempt to further optimize isolation beyond that achieved in the tests of Reference 2 was made. Design considerations required for a wider band of vertical isolation are discussed in Appendix II.

Isolation Substantiation (continued)

No response sweep is presented for the pilot-vertical station due to a vertical excitation because of an instrumentation malfunction. However, Figure 33, which shows pilot-vertical response due to a combined longitudinal/vertical excitation is presented. Since isolation is shown for both the combined longitudinal/vertical excitation and pure longitudinal excitation (Figure 41), it is concluded that isolation at the pilot vertical station exists due to vertical excitation alone. This conclusion is further substantiated in Figures 33 through 35 which show reduced vertical response at the other fuselage locations due to vertical excitations.

ROTOR LOADS MEASUREMENT AND CORRELATION

The principal objective of these tests was to verify the feasibility of simultaneously providing active transmission isolation and measurement of rotor loads. System calibration tests were performed during which known steady, steady-state vibratory and transient loadings were applied to the simulated rotor head, through load application systems installed on the test vehicle, or by known vehicle weight. Transducers installed on the rotor head , transmission housing, isolators, and torque restraint links were monitored and recorded to obtain those parameters necessary to measure the applied loads. All recorded data was processed using the Computer program described in Appendix III. The resulting measured loads are compared in Tables 2 and 3, with the known applied loads to establish the accuracy of the isolation system as a rotor loads measurement device.

Conditions investigated included:

a) Combinations of steady rotor lift, propulsive force and main rotor torque.

b) Combinations of principal rotor vibratory excitation at frequencies of 10, 18.5 and 30 HZ, in combination with steady rotor lift.

c) Steady rotor lift and vertical transient load.

d) Steady rotor lift and transient propulsive force.

e) Simulated flight conditions including vibratory loads.

Magnitudes of all rotor loads applied are representative of levels which can be reasonably anticipated in actual flight.

Steady lift was provided by the bungee suspension system which raised the entire test vehicle off the deck to simulate free flight. Measurement of the rotor lift was accomplished by monitoring the loads present in each isolator. Excellent correlation between applied and measured steady rotor lift was obtained. The error in measuring rotor lift, alone and in the presence of superimposed steady torque, propulsive force, and vibratory loadings, averaged 2 percent of the applied lift. Linearity of the measurement system was verified by incrementally varying the lower body weight. The average error over the entire range was 2 percent of applied lift. These results are presented In Figure 44.

Steady main rotor torque was applied in the presence of steady lift and with combinations of propulsive force and vibratory loads, utilizing the torque application system described previously. In all cases, the measured torque correlated to within 2 percent of applied torque.

The incremental torque loadings presented in Figure 45 show that the torque measurement is also linear.

Propulsive forces were measured with the load cells in the longitudinal transmission torque restraint links, to a 1 percent accuracy when measured alone. The results of incremental loading, to 4000 pounds, (Figure 46), also exhibited linearity. However, when propulsive force was measured during the simultaneous application of main rotor torque, the error in measured propulsive force increased substantially. This decrease in accuracy is largely attributed to deficiencies in the test set-up which includes; large secondary inplane loads introduced by the torque application system and the in-plane restraint links being configured so as to provide simultaneous measurement of main rotor torque, side force, and propulsive force. This coupling and resultant decrease in accuracy was predicted in the RSRA pre-design study (Ref. 1). These test results therefore substantiate the requirement for a rotor balance configuration in which a single longitudinal load sensor and two lateral load sensors are employed to decouple the measurement of propulsive force and main rotor torque. Such a configuration will provide maximum propulsive force measurement accuracy although sacrificing side force measurement accuracy. The 2% accuracy obtained in measuring all principal rotor forces is consistent with the projections of the RSRA pre-design study (Ref. 1).

Vibratory loads were applied at frequencies of 10, 18.5 and 30 HZ. Examination of oscillograph rolls indicated that the sensitivities utilized did not provide adequate resolution of the vibratory signals required for accurate phase measurement. Test conditions were repeated, utilizing magnetic tape and signals were amplified. Examination of this test data at the frequencies of 18.5 and 30 HZ where most effective isolation resulted, indicated that all vibratory transducer signals were either at 0° or 180° phase angle with respect to the reference force signal. A sample of test data is shown in Appendix III - D. However, difficulty in reading phase remained at the 10 HZ frequency and is attributed to the closer proximity of the excitation frequency to resonances and the resulting modal coupling. This difficulty is identified as the source of larger errors in measuring vibratory loads at 10 HZ.

At the 18.5 and 30 HZ test frequencies, the measurement of applied load was strongly dependant upon accelerometer data. The average error in measuring total vibratory force at these frequencies is 20 percent (Figure 47).

Three vibratory test points at which the error in measuring vibratory load varied from 25 - 50 percent are presented in Appendix IV. In these cases, the contribution of the accelerometer data to the measurement of the vibratory load varied from 65 to 130 percent of the net load. The acceleration levels recorded varied from .06 to .23 g's which is equivalent to a range of 3 to 10 percent of the full scale sensitivity of the accelerometers.

It is concluded that the future use of piezoelectric accelerometers are required to produce improved accuracy of accelerometer and, therefore, vibratory load measurement. It is projected that vibratory load measurement accuracy can be substantially improved through the use of these transducers.

It can also be concluded from the results previously discussed that vibratory rotor loads can be most accurately measured when the airframe is effectively isolated. Under this condition, measurement of vibratory loads is predominately dependent upon measuring amplitude and phase of transmission accelerations. Future tests should make provisions for providing maximum possible resolution of vibratory signals, thus maximizing phase readout and vibratory load measurement accuracy.

Transient load tests were conducted to evaluate the ability of the rotor balance system to respond to and measure simulated flight maneuver loads. Longitudinal and vertical step input loads of 4,000 and 10,000 pounds, respectively, were applied, and data was recorded on an FM tape system. Data was digitized and fed into computer programs (Appendix III-B), where it was processed, and the time histories of applied load, measured load, and relative motions between the transmission and airframe were defined. The transient data presented in Figures 48 to 53 represent time histories of load and displacement over an elapsed time of five seconds, and are computed with a sampling rate of 240 data points per second. Applied and measured loads were compared for measurement accuracy and responsiveness of the force measuring system. The graphs presented are plotted individually for ease of comparison.

The time histories of the applied transient loads were determined by the load in the force application device and the response of the simulated transmission/rotor head. The measured forces were tabulated from transducers in the active isolators and torque restraint links.

As shown, the active isolation system was able to accurately measure the time history of the applied force even though the rate of application far exceeds that which would be anticipated in flight. Variance between applied and measured load is again attributed to accelerometer sensitivities, which in this case plays the predominant role in defining the time history of applied load. Of particular significance to in-flight operation is the fact that even under the application of these severe transient loads, relative angular and vertical motion between the transmission and airframe are well within the design tolerances of control systems and high speed engine drive shafts.

CONCLUSIONS

The testing performed under this program has successfully demonstrated the feasibility of providing simultaneous active transmission vibration isolation and measurement of steady, vibratory and transient rotor loads. As a result of these tests, the following conclusions are reached:

BENCH TEST

(1) Active isolator units measure steady and transient loads to better than 1 percent of applied load about a linear bias which can be removed through calibration.

(2) The presence of vibratory loads do not affect steady load measurement accuracy.

(3) Vibratory loads can be measured to within 4 percent of applied vibratory load, independent of excitation frequency.

(4) Load measurement accuracy is independent of variations in basic isolator operating characteristics which include servo gain, air precharge pressures, and hydraulic damping.

SYSTEM TEST

(1) Isolation system modifications required for rotor loads measurement do not affect isolation characteristics.

(2) The configuration tested produced significant vibration reductions over the entire frequency range, above isolator resonances.

(3) The average error in measuring steady rotor lift and main rotor torque is 2 percent of applied load, independent of the flight condition simulated and the presence of vibratory loads.

(4) The average error in measuring propulsive force is 1 percent of applied load, independent of the presence of vibratory loading.

(5) The configuration tested which was not originally designed for rotor force measurement utilizes transducers which simultaneously measure both main rotor torque and propulsive force. This coupling produces a substantial degradation in propulsive force measurement error when main rotor torque is applied simultaneously. This substantiates the results of pre-design studies (Ref. 1) which identified this problem and resulted in a proposed RSRA configuration which would decouple propulsive force and main rotor torque measurement.

(6) At frequencies where effective isolation to all excitations was obtained (above 3/rev on the CH-53A), the average error in measuring vibratory rotor loads was established as 20 percent of applied loads. This error is attributed predominantly to the accuracy of accelerometers utilized. It is anticipated that the use of piezoelectric accelerometers would substantially improve this accuracy.

(7) The active transmission isolation system is able to accurately measure the time histories of transient loads while maintaining relative displacements between the transmission and airframe within design tolerances of control systems and high speed engine drive shafts.

RECOMMENDATIONS

It is recommended that any Rotor Force measurement system for the RSRA contain the following features:

(1) A single longitudinal load sensor to decouple the measurement of propulsive force and main rotor torque.

(2) Piezoelectric accelerometers to provide greater sensitivity and accuracy in determining transmission and rotor load accelerations required for transient and vibratory load measurement.

(3) Provisions in data acquisition and processing systems to provide maximum possible resolution of vibratory signals required for accurate phase definition.

It is also recommended that the active isolator system be developed for vibration control and rotor loads measurement on the RSRA for slowed rotor operation. The recommended steps for further development are:

(1) Design analysis of overall flight vehicle/isolation system dynamic characteristics, including:

  (a) Rotor stability, stress levels, control loads, and ground/air resonance.

  (b) Control system/isolator coupling and stability augmentation system.

(2) Detail Design including:

  (a) Variable isolator operating characteristics.

  (b) Rotor Balance instrumentation.

  (c) Fail safe and reliability considerations.

  (d) Hydraulic supply and temperature control.

  (e) Engine and control systems interface.

(3) Fabrication and testing on the RSRA including:

  (a) Structural proof tests.

  (b) Tiedown tests to substantiate compatibility of dynamic components.

  (c) Flight tests.

Page Intentionally Left Blank

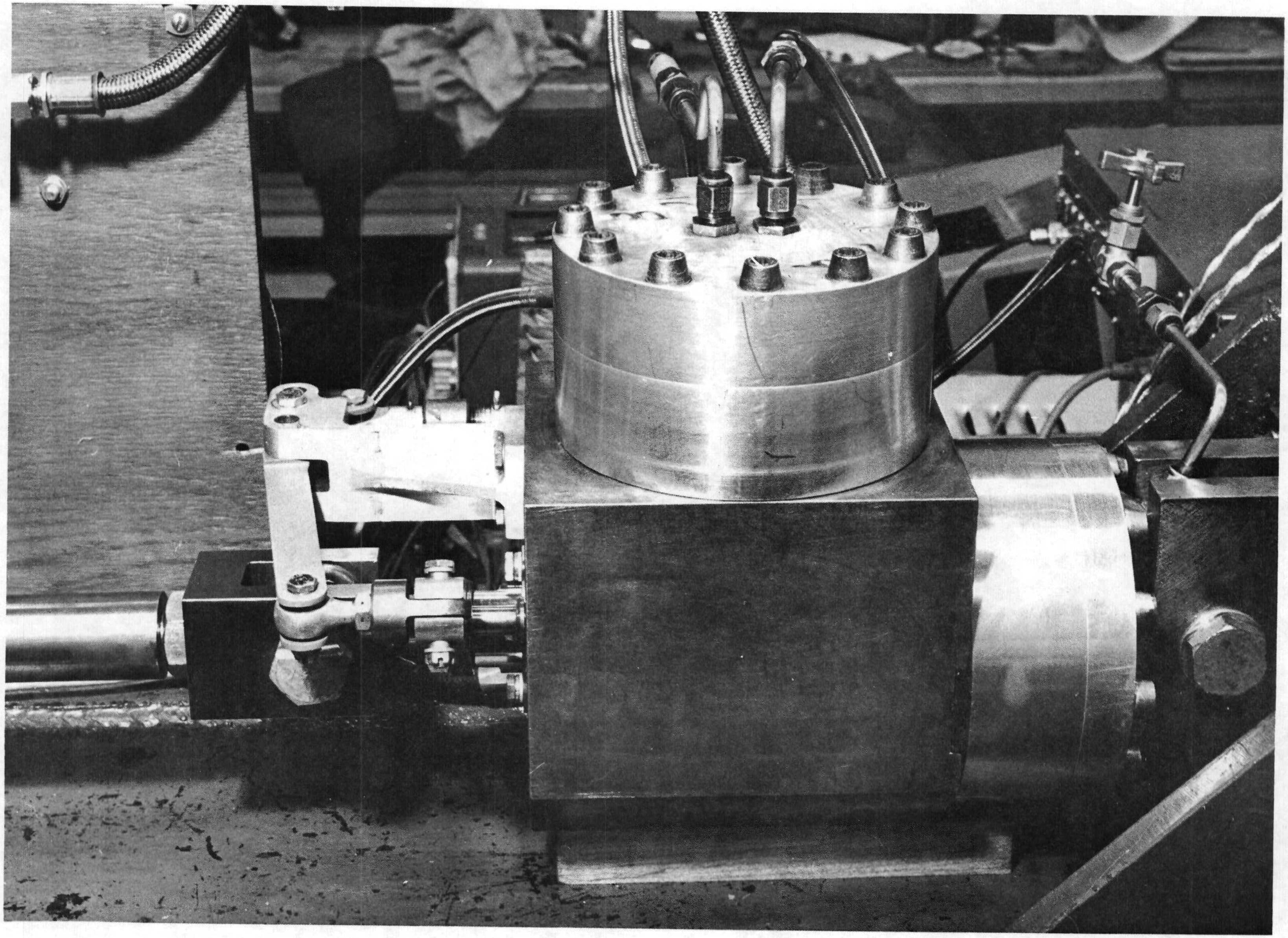

Figure 1. - Assembled Active Isolator.

Figure 2. - Disassembled Active Isolator.

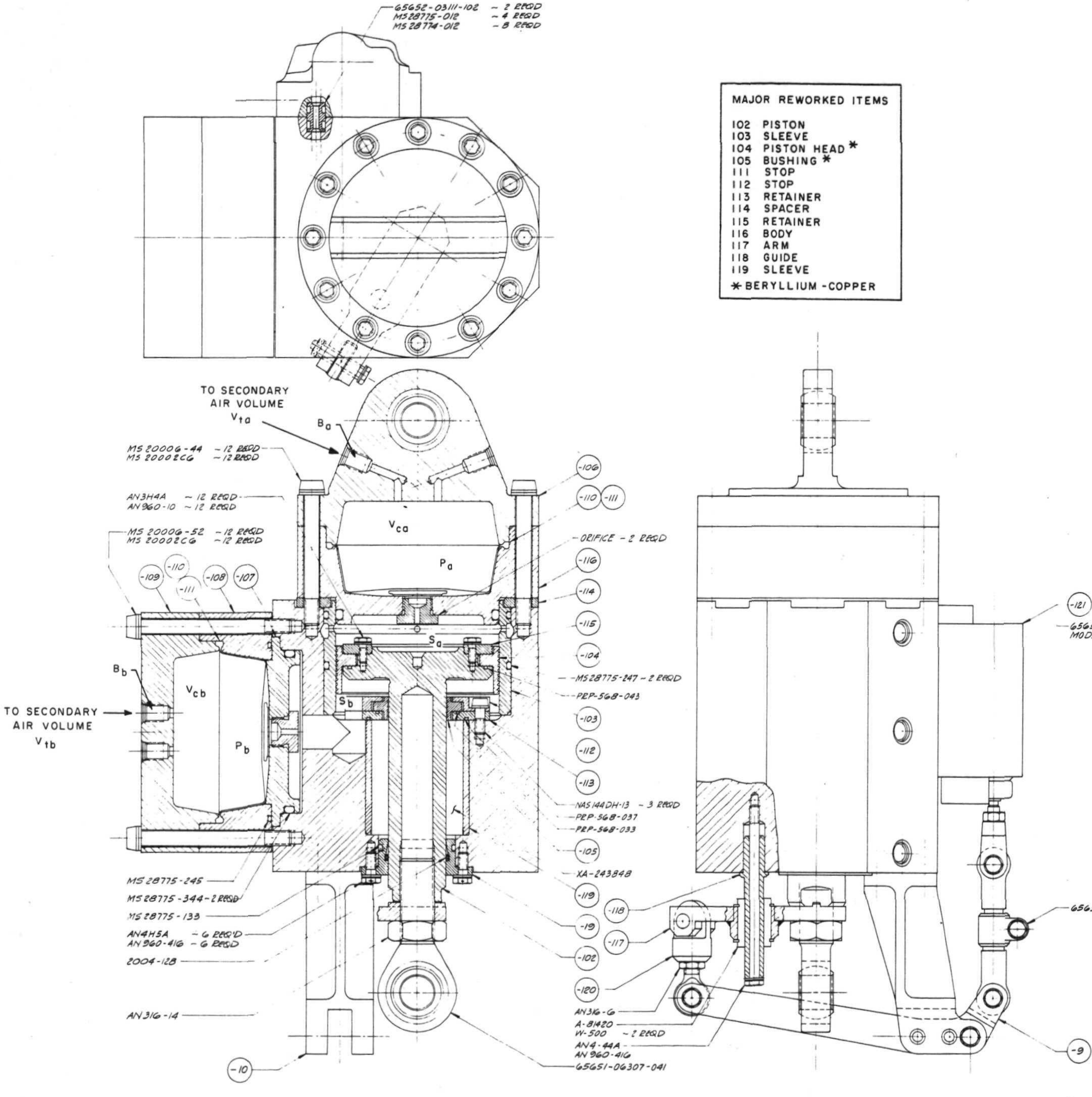

Figure 3. - Active Isolator Assembly Drawing.

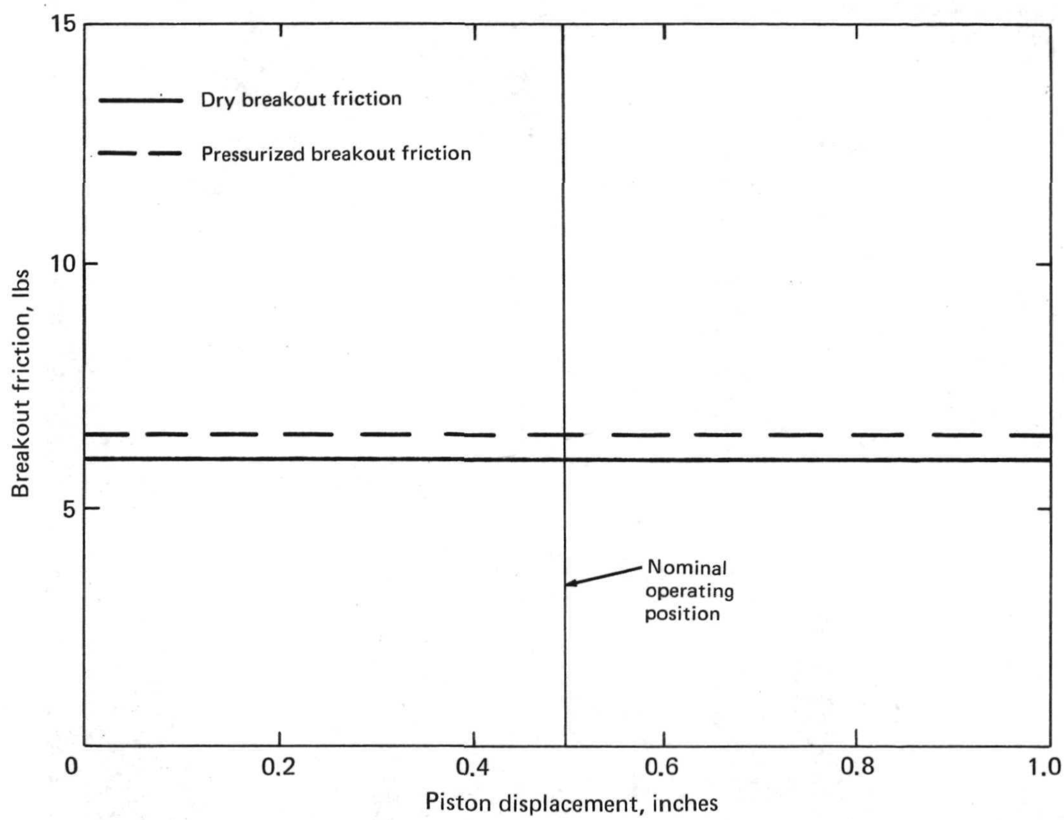

Figure 4. - Piston Breakout Loading.

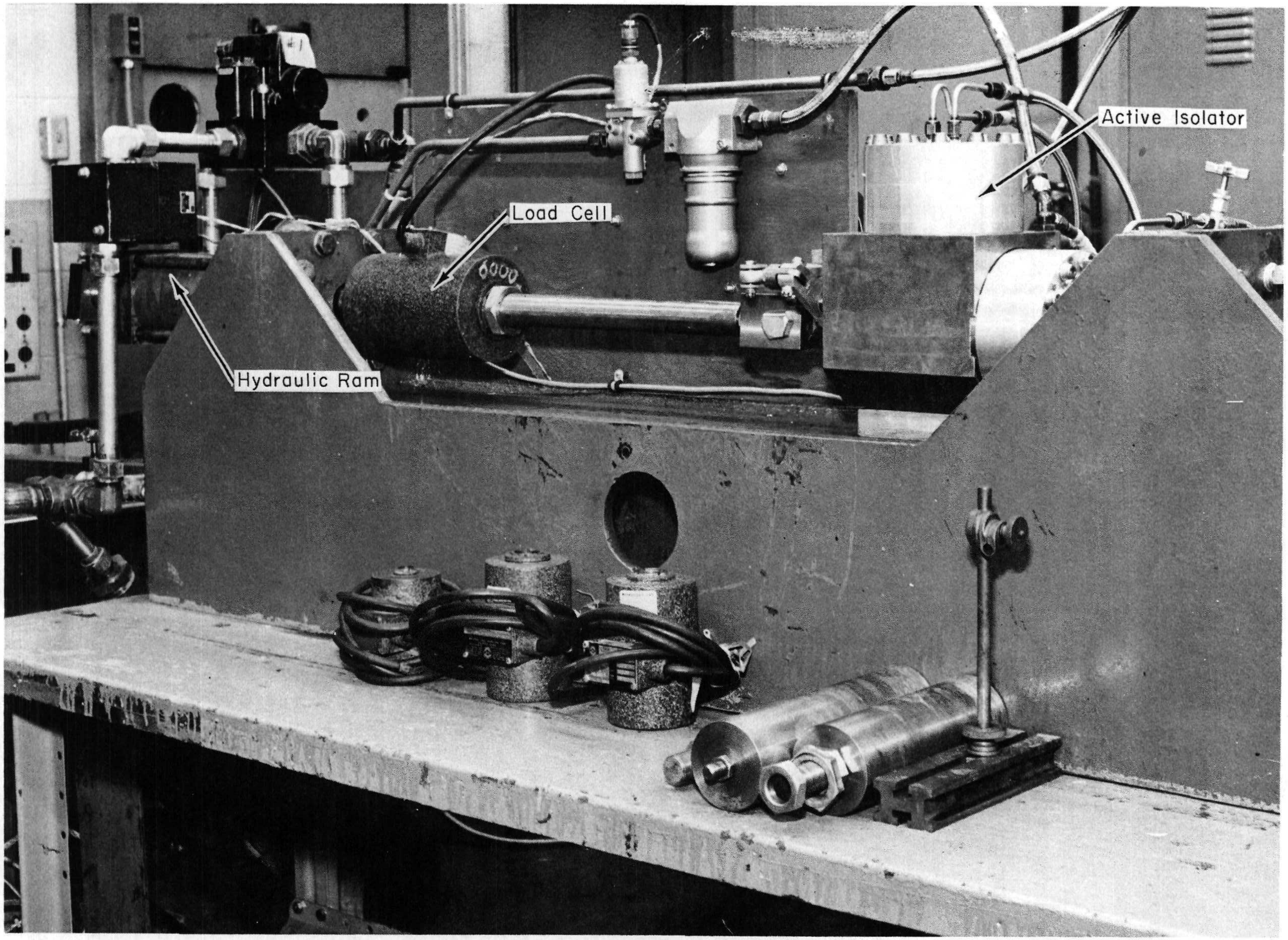

Figure 5. - Bench Test Facility.

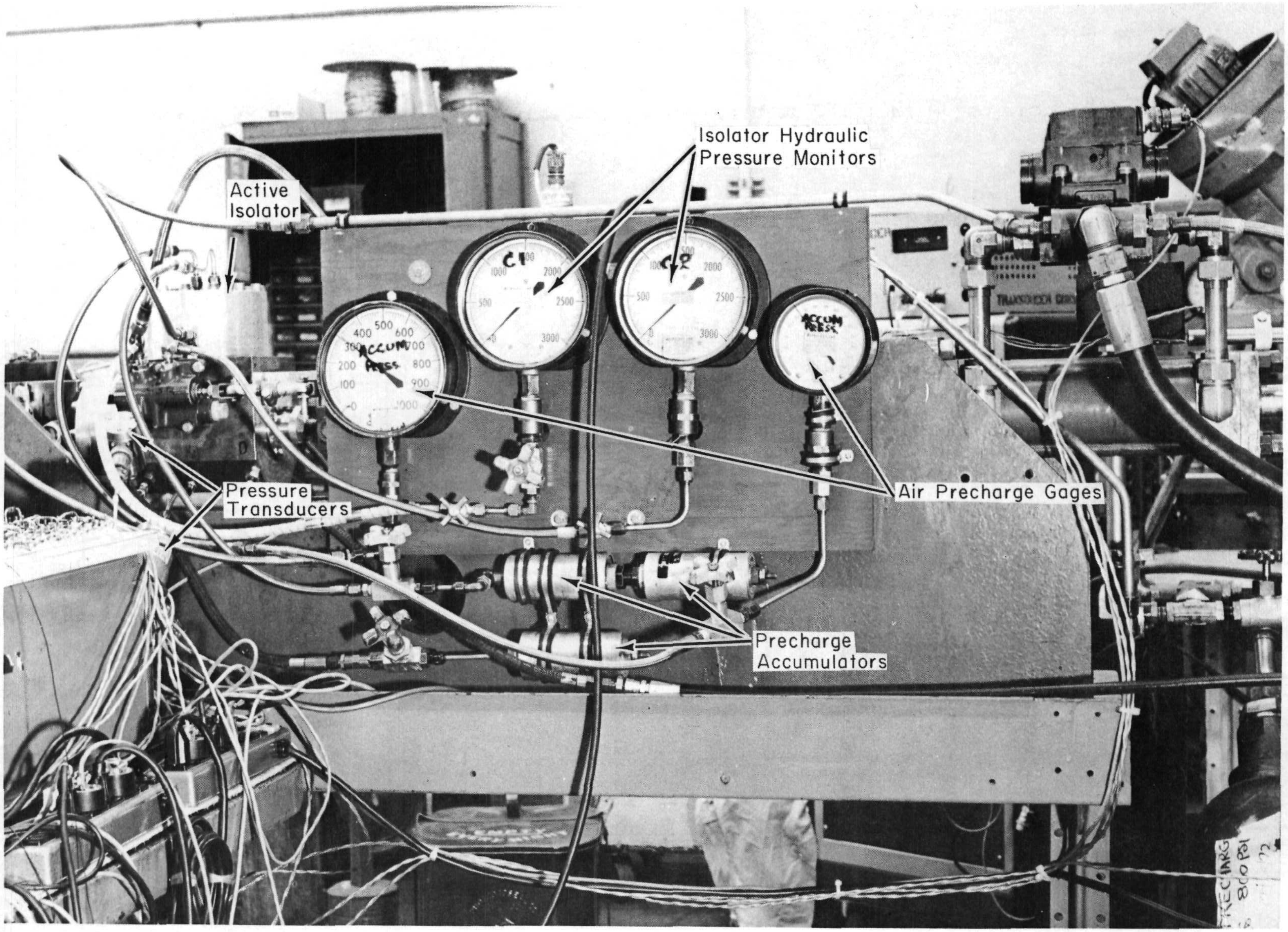

Figure 6. - Isolator Instrumentation.

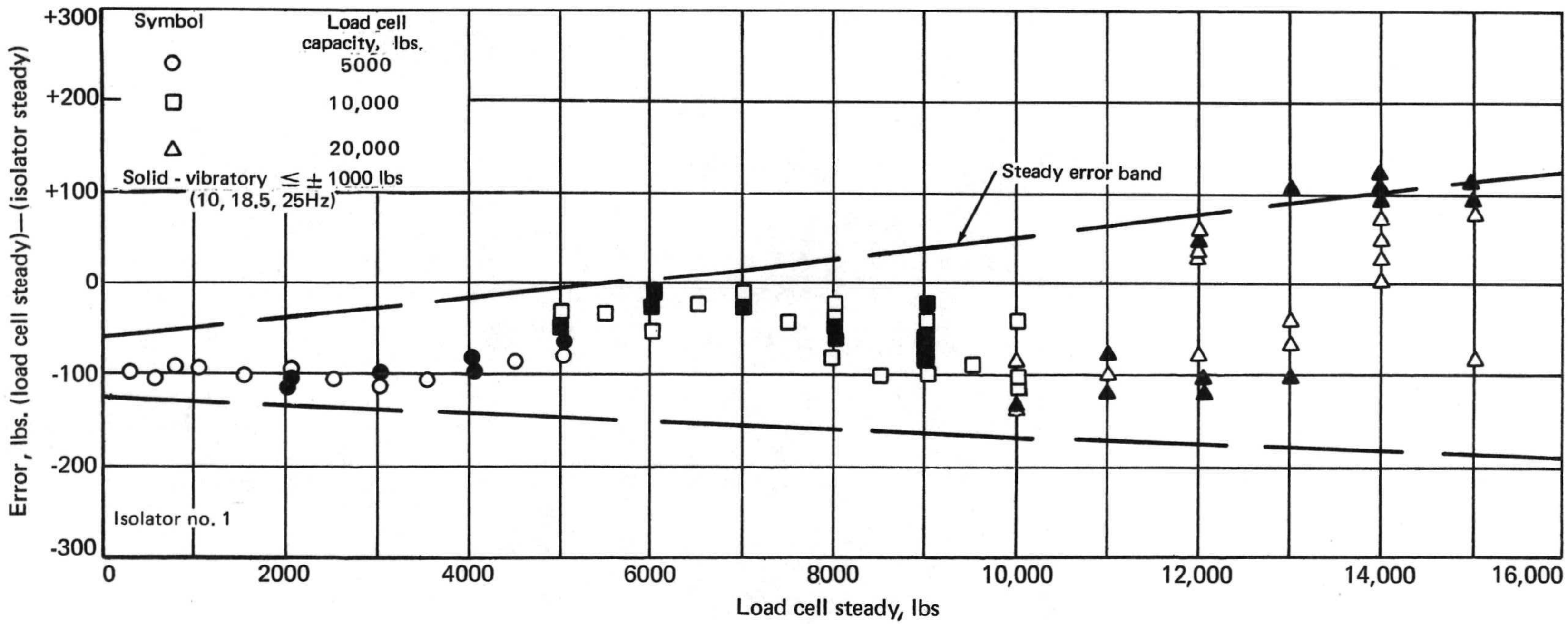

Figure 7. - Steady Load Calibration at Basic Isolator Settings - Isolator No. 1.

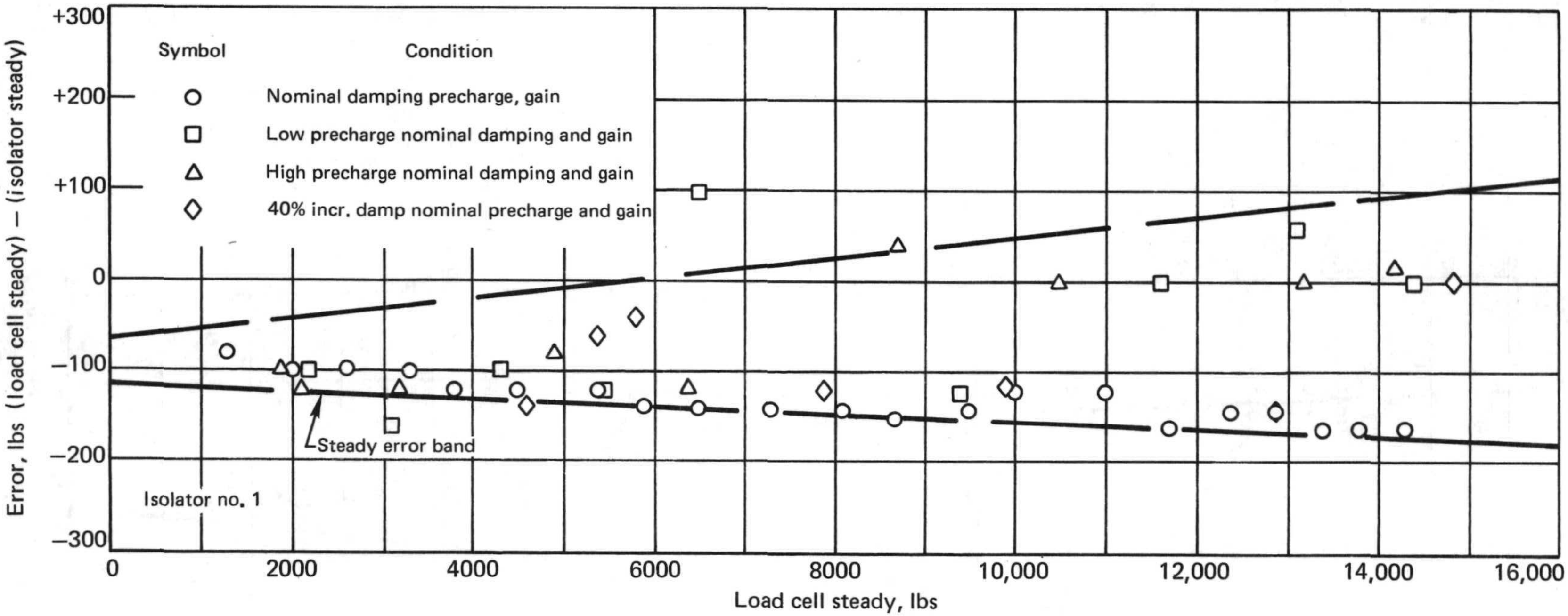

Figure 8. - Transient Load Calibration - Isolator No. 1.

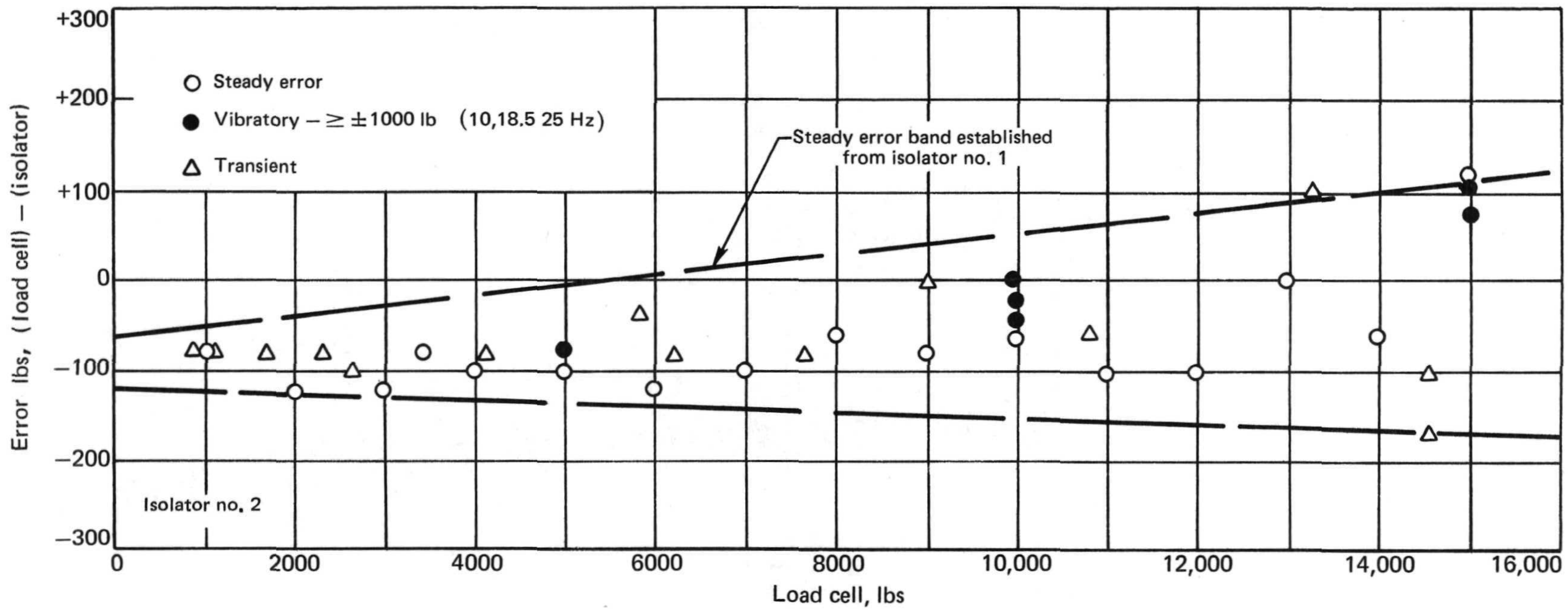

Figure 9. - Steady Load Calibration at Basic Isolator Settings -- Isolator No. 2.

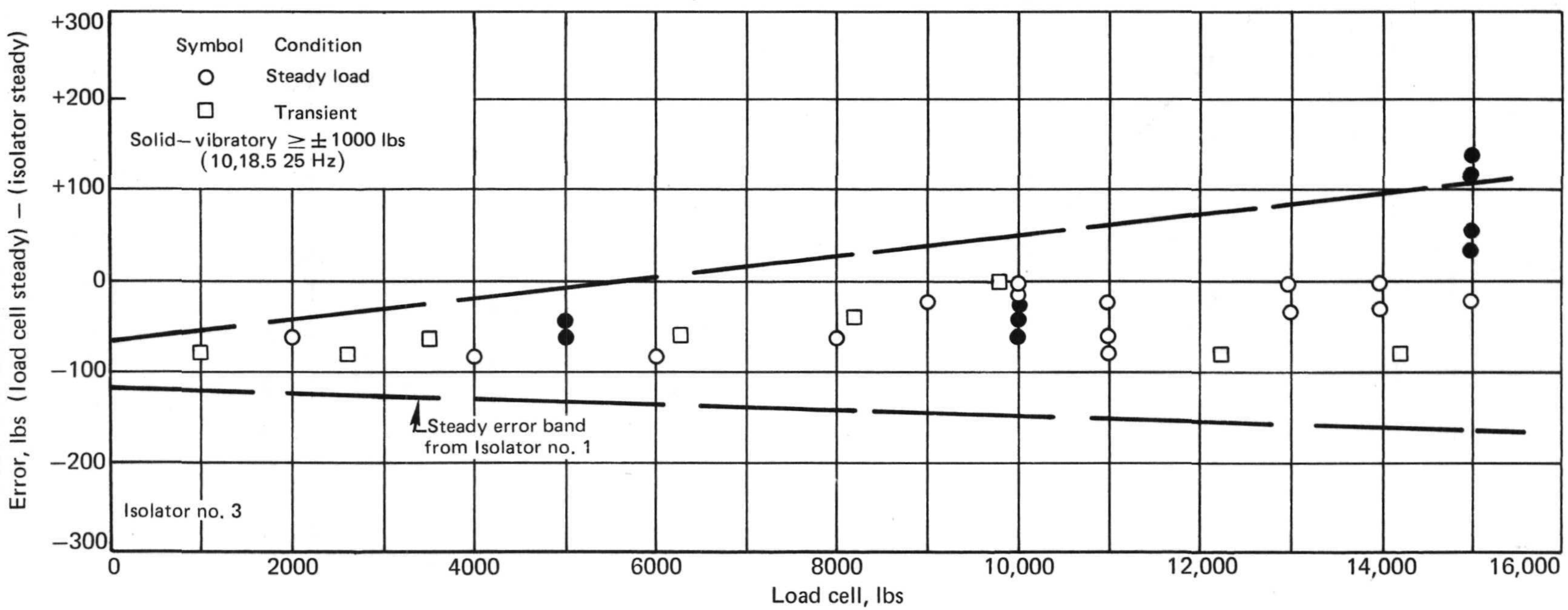

Figure 10. - Steady Load Calibration at Basic Isolator Settings - Isolator No. 3

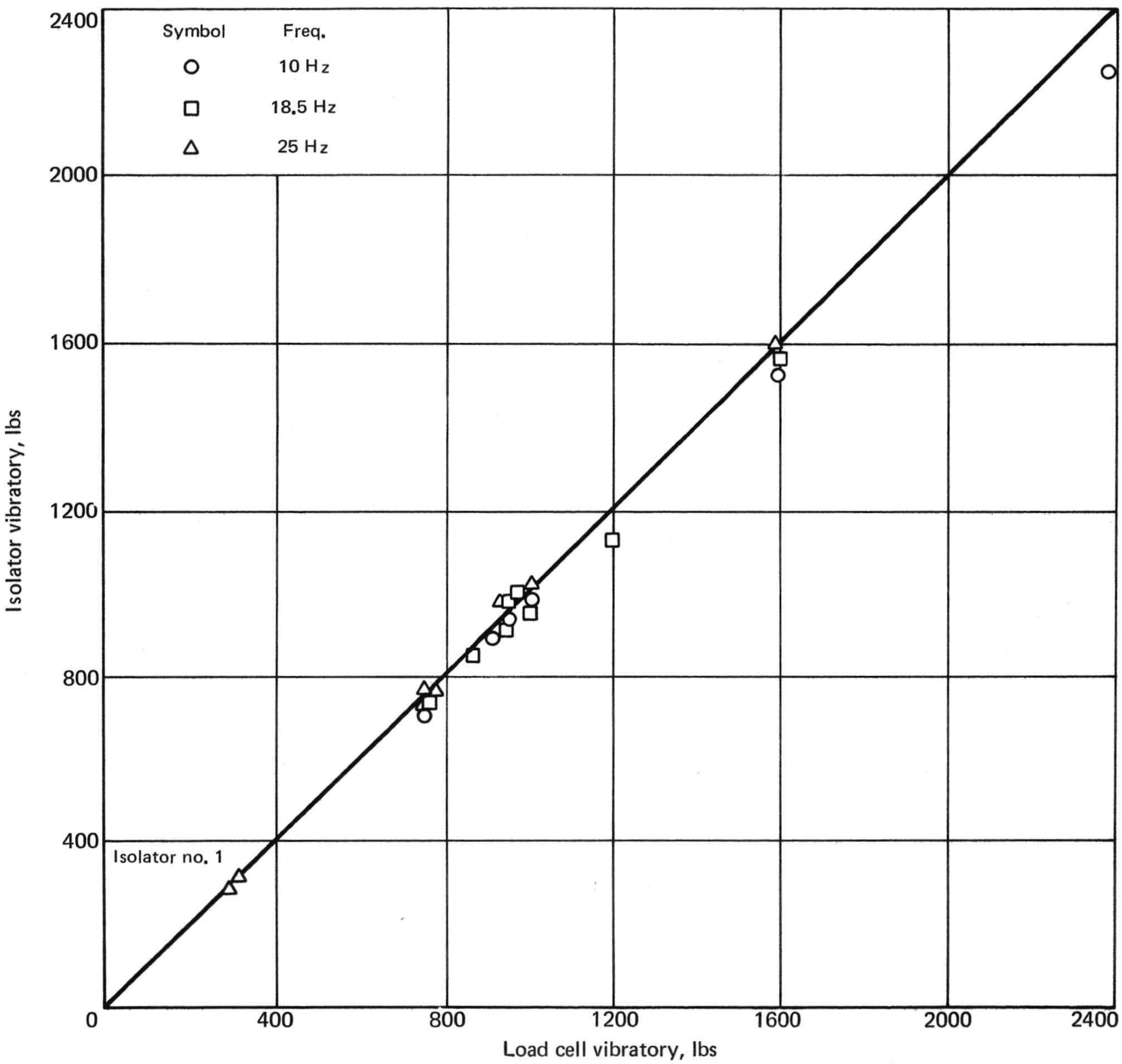

Figure 11. - Vibratory Load Calibration at Basic Isolator Settings - Isolator No. 1.

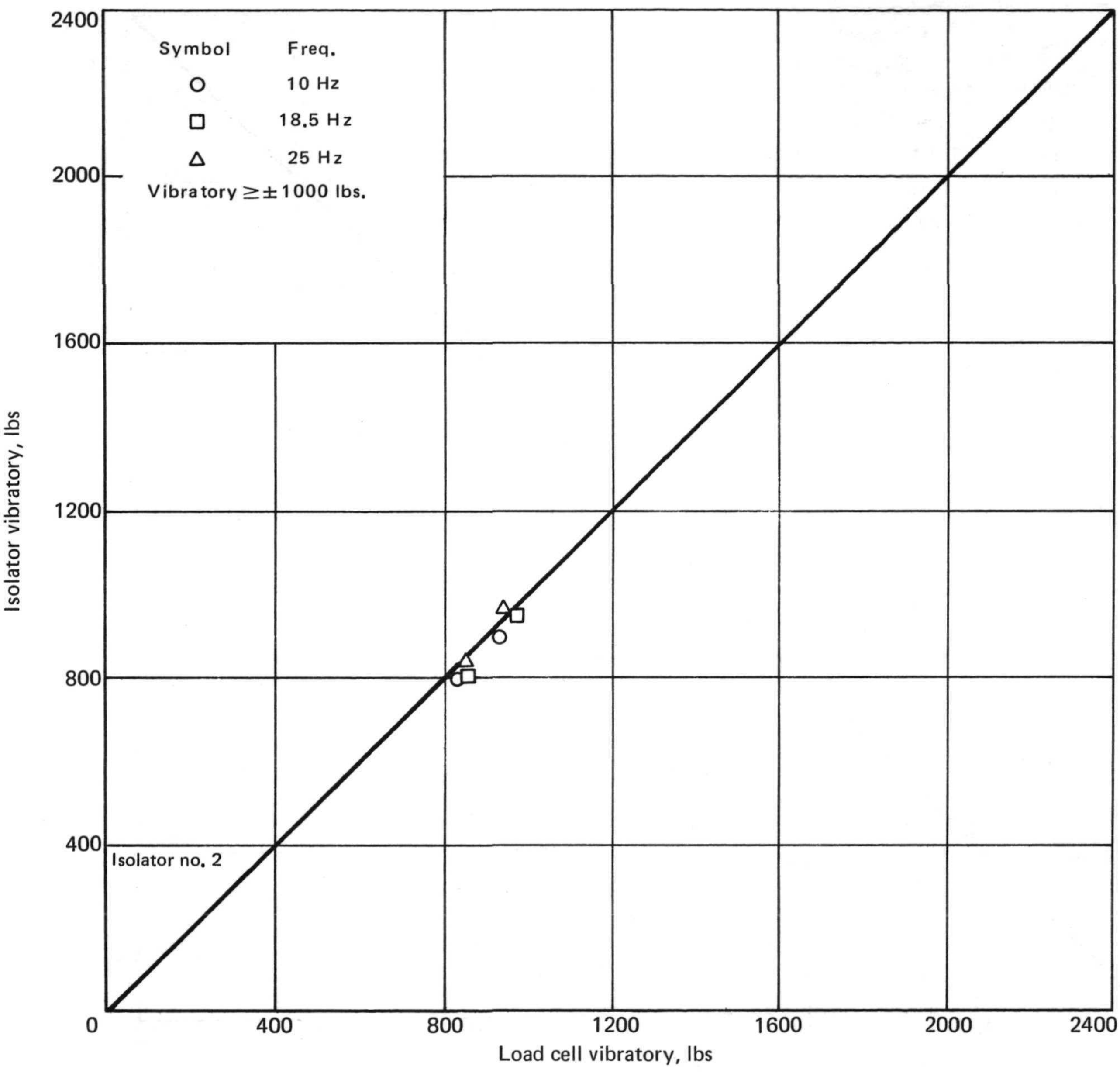

Figure 12. - Vibratory Load Calibration at Basic Isolator Settings - Isolator No. 2.

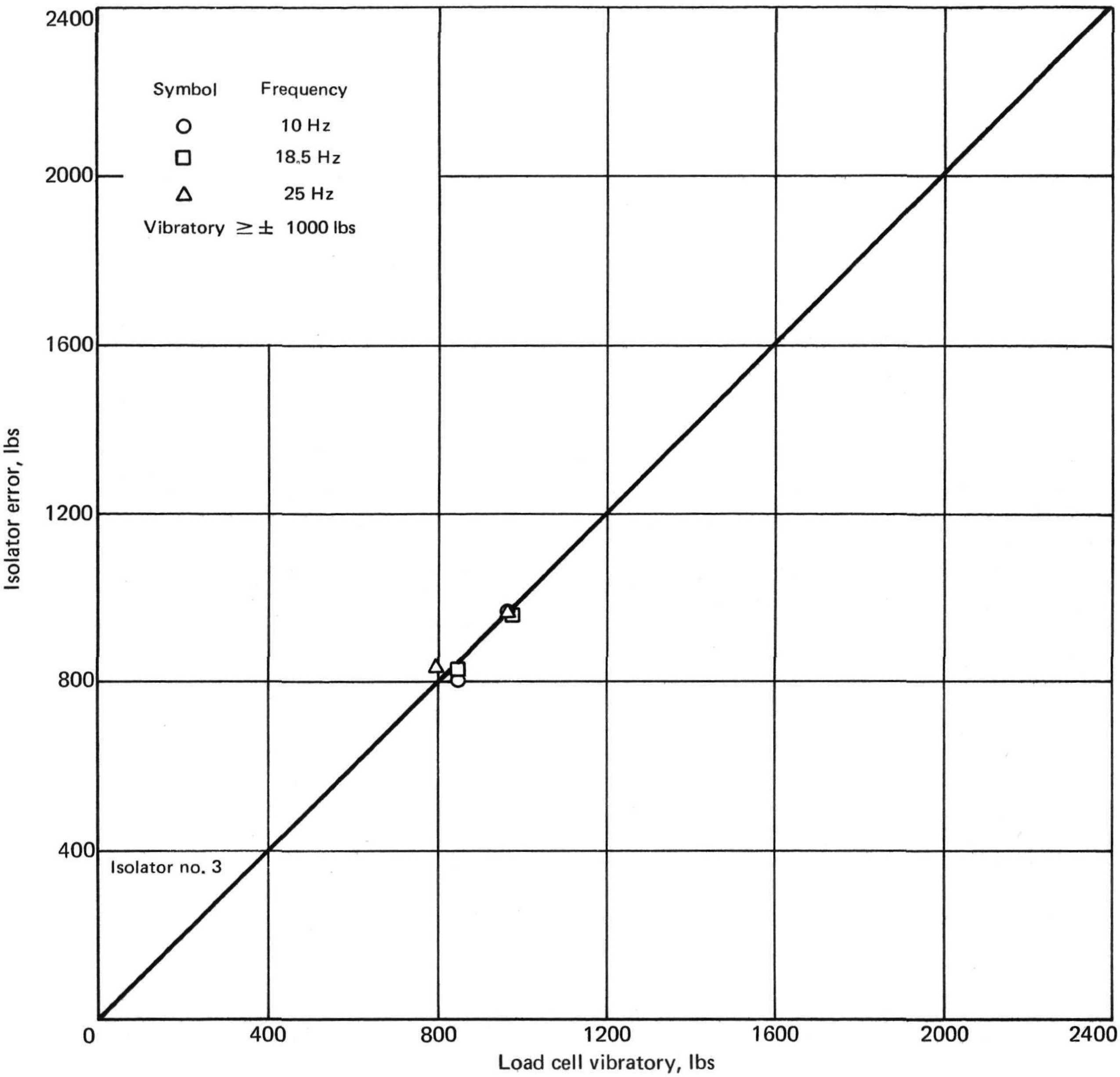

Figure 13. - Vibratory Load Calibration at Basic Isolator Settings - Isolator No. 3.

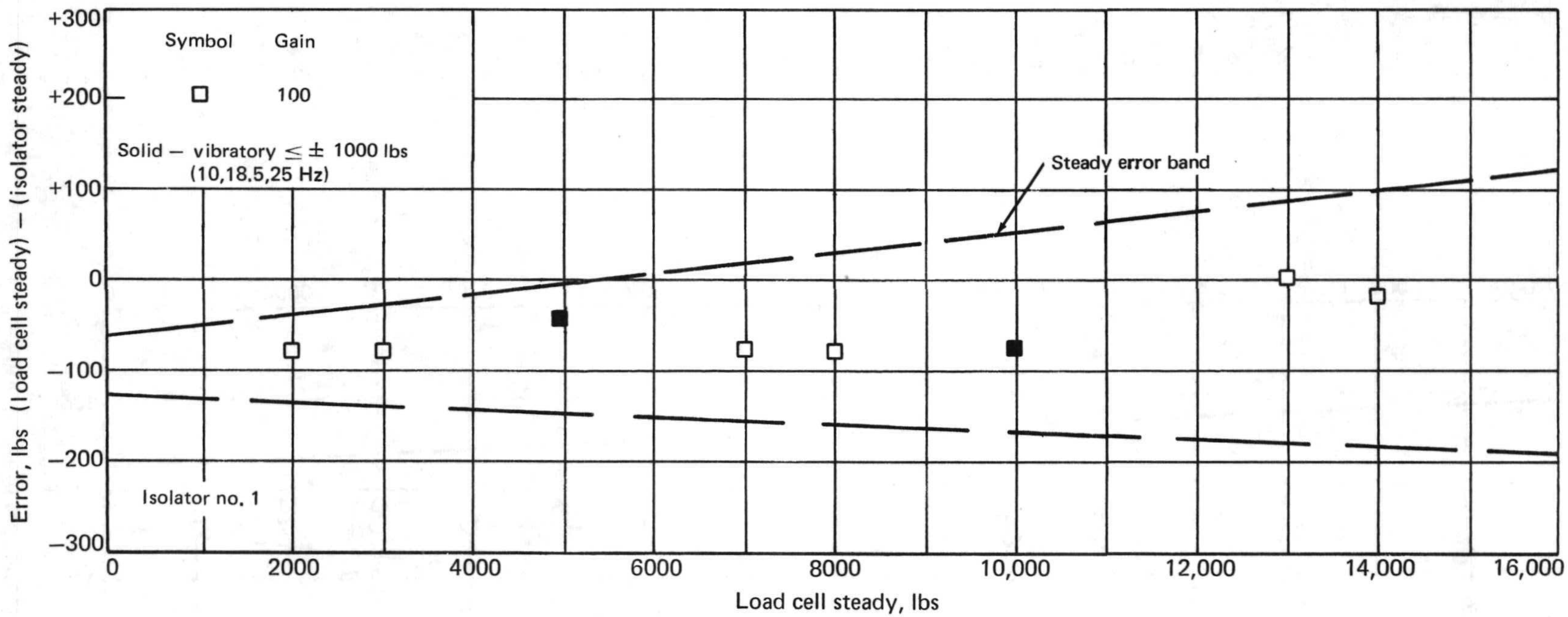

Figure 14. - Steady Load Calibration With Increased Precharge (P_A = 500 psia and P_B = 1820 psia) and Gain Variation - Isolator No. 1.

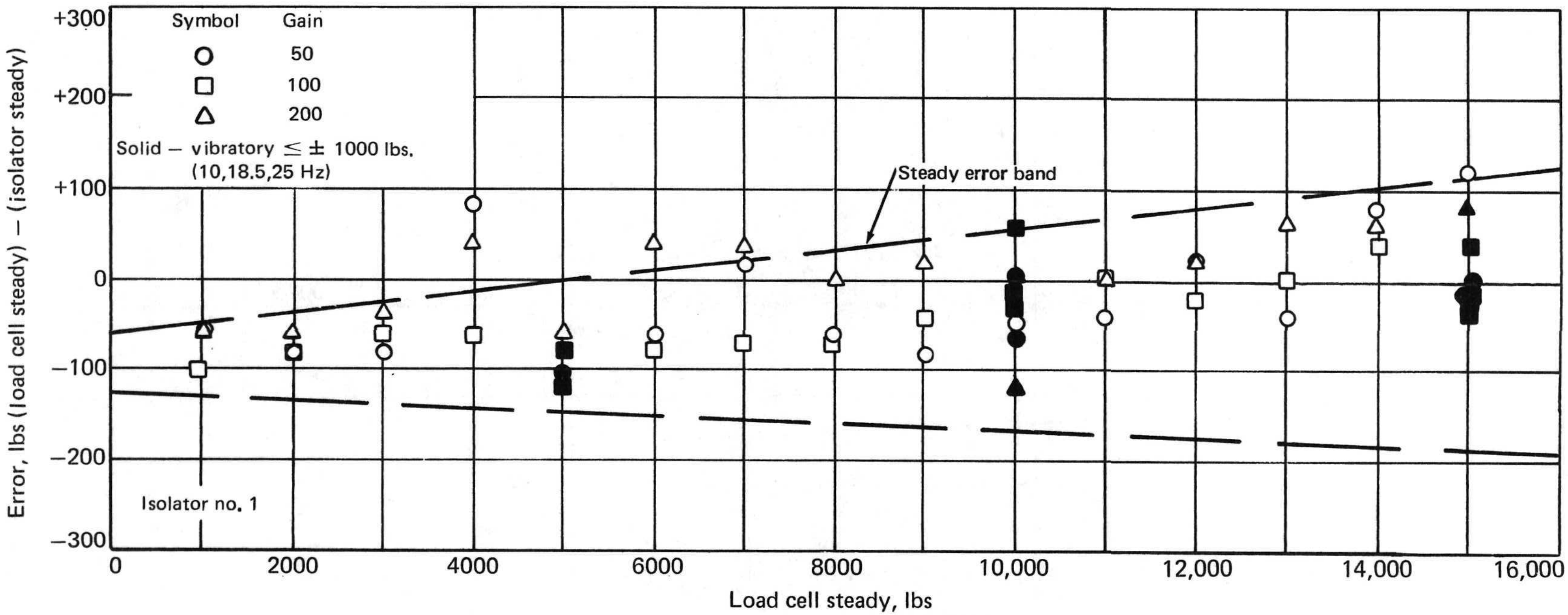

Figure 15. - Steady Load Calibration With Reduced Precharge (P_A = 150 psia and P_B = 550 psia) and Gain Variation Isolator No. 1.

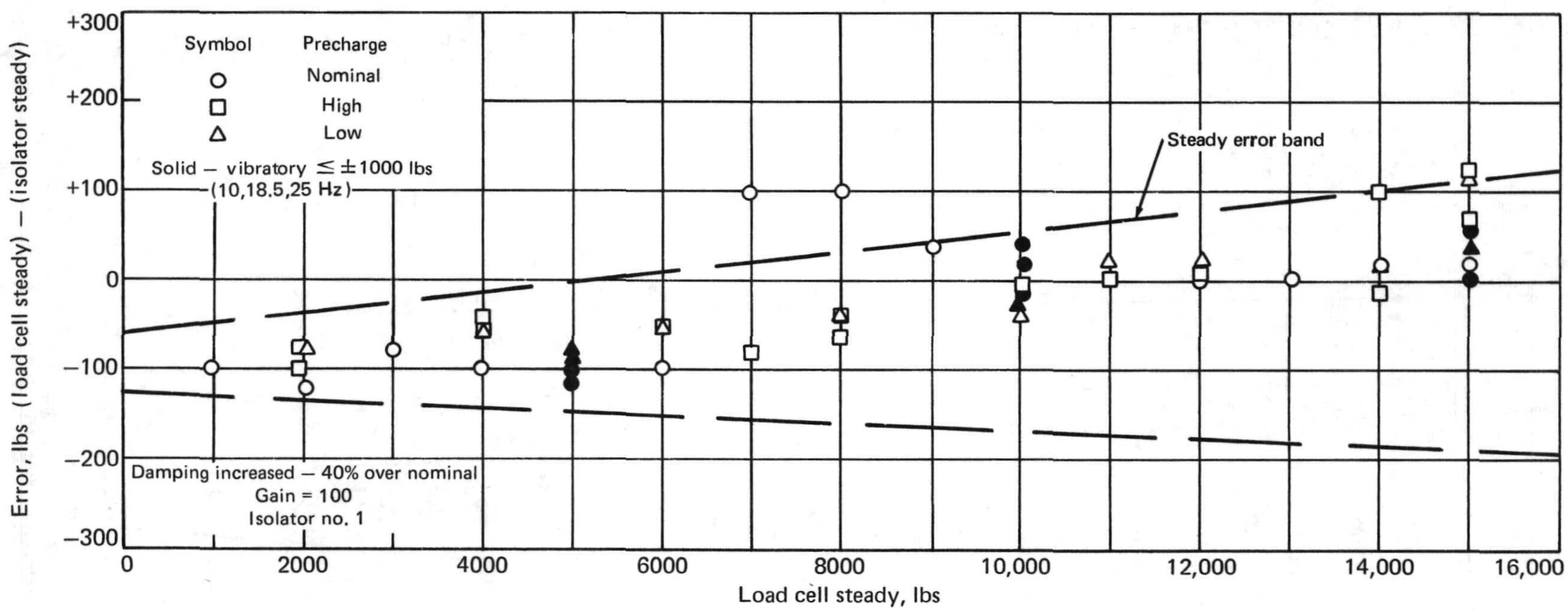

Figure 16. - Steady Load Calibration With Precharge and Damping Variations - Isolator No. 1.

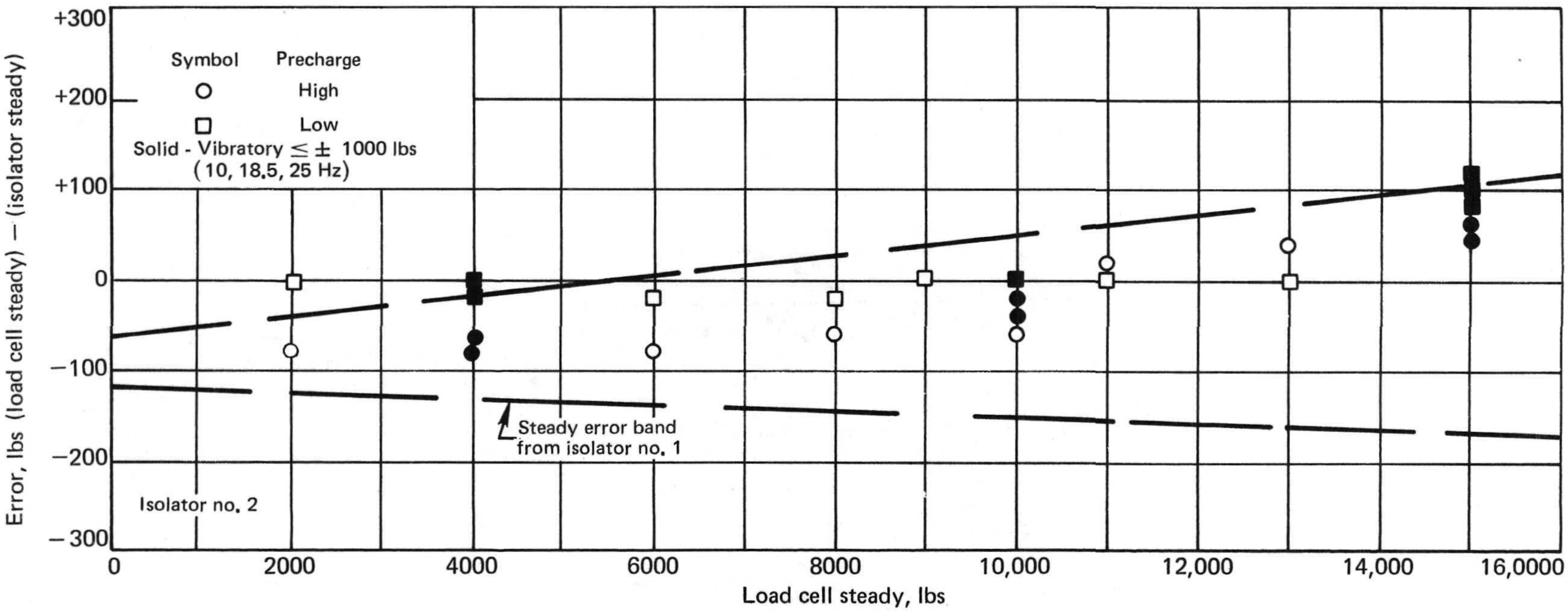

Figure 17. - Steady Load Calibration With Precharge Variations - Isolator No. 2

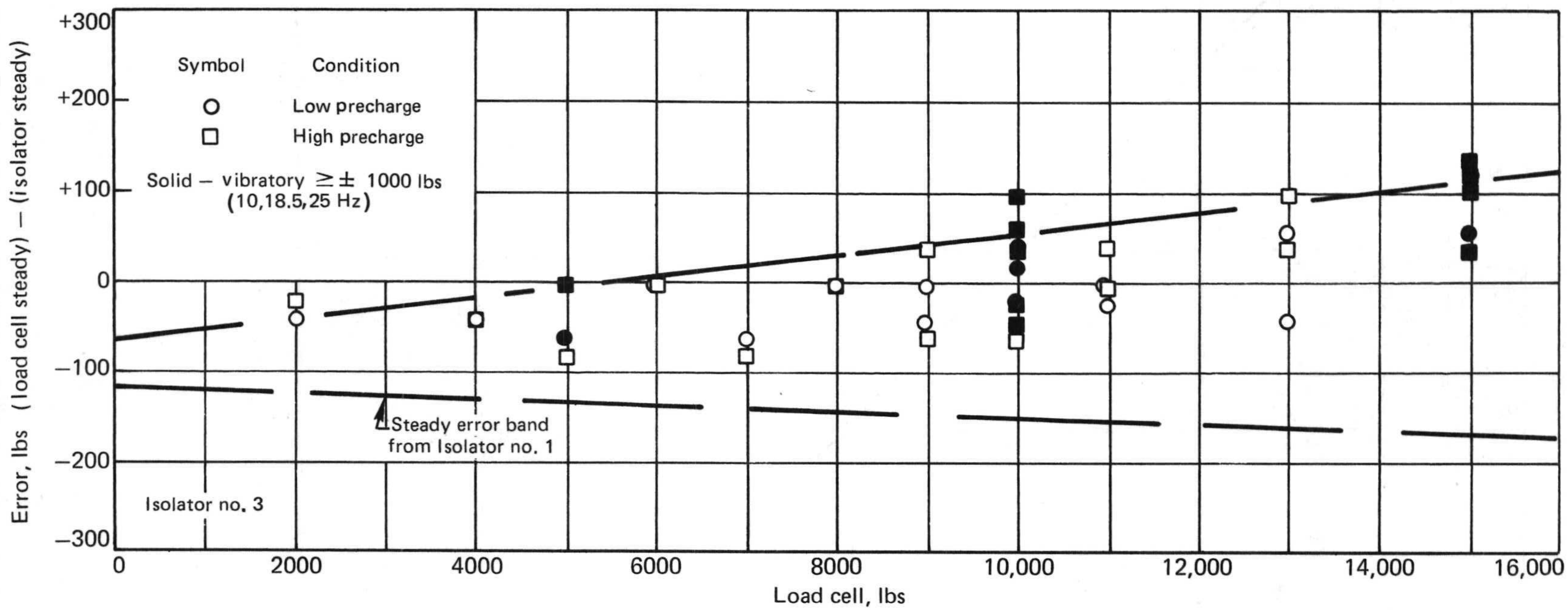

Figure 18. - Steady Load Calibration With Precharge Variations - Isolator No. 3.

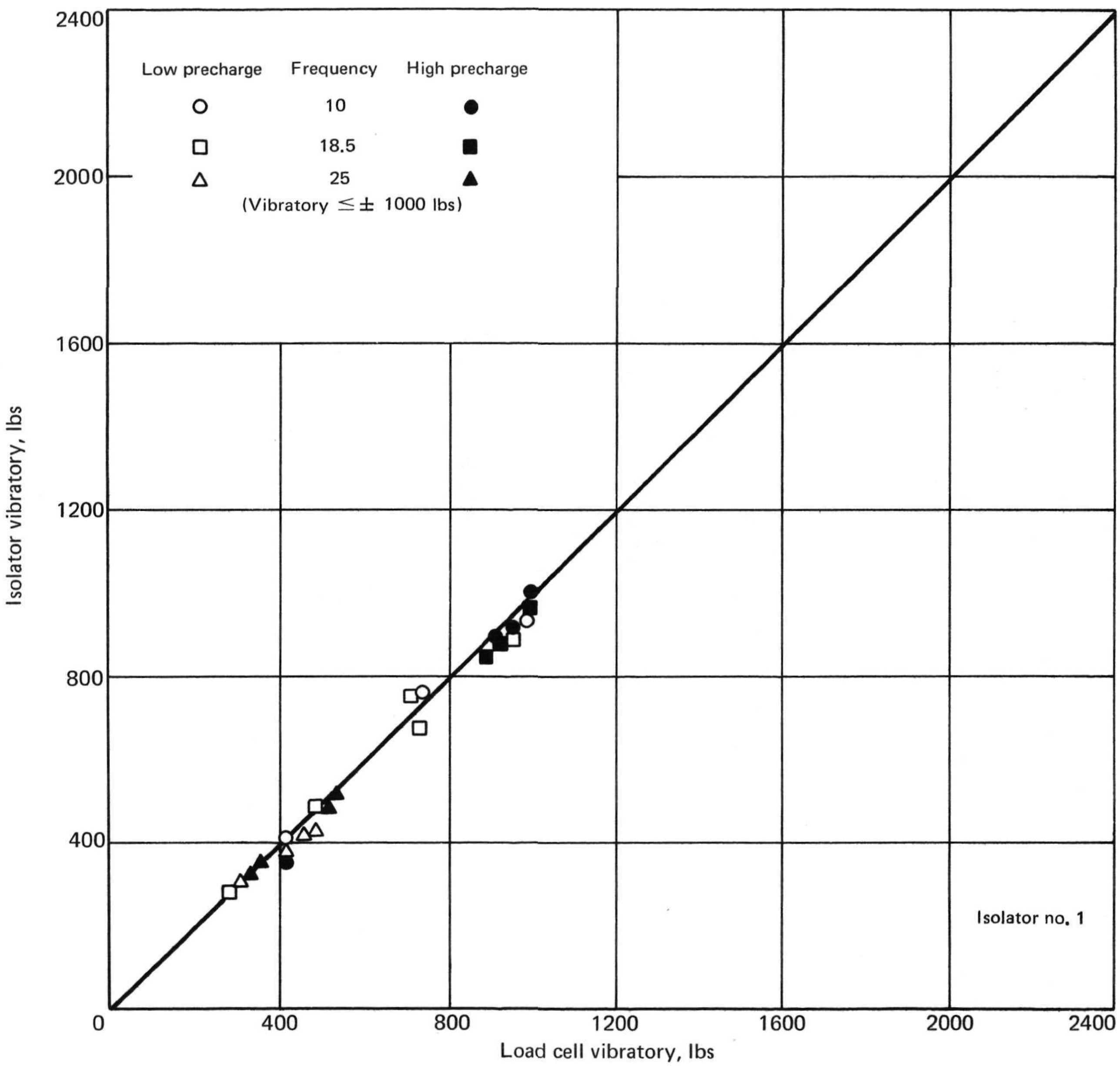

Figure 19. - Vibratory Load Calibration With Precharge Variations - Isolator No. 1.

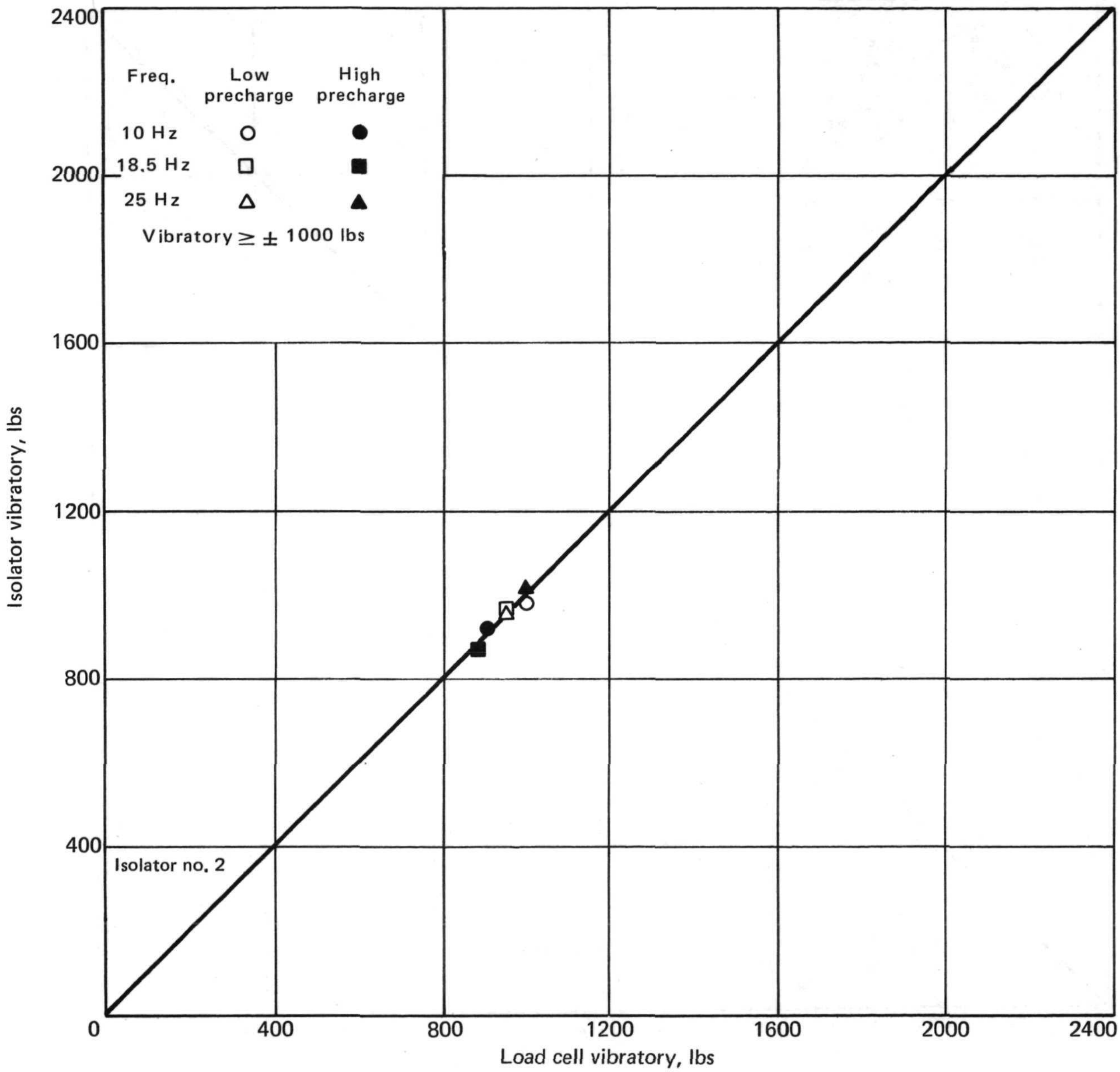

Figure 20. - Vibratory Load Calibration With Precharge Variations - Isolator No. 2.

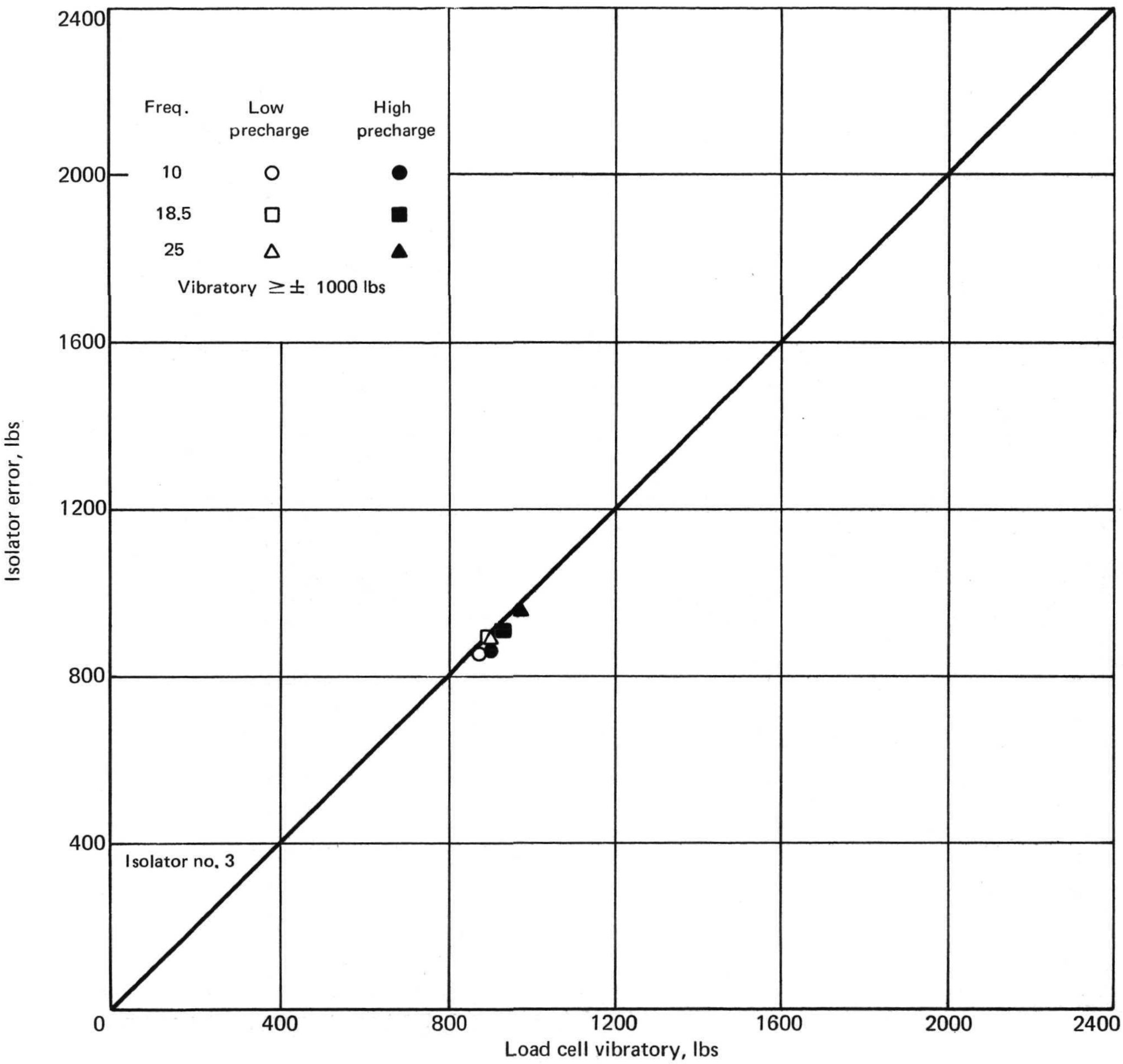

Figure 21. - Vibratory Load Calibration With Precharge Variations - Isolator No. 3.

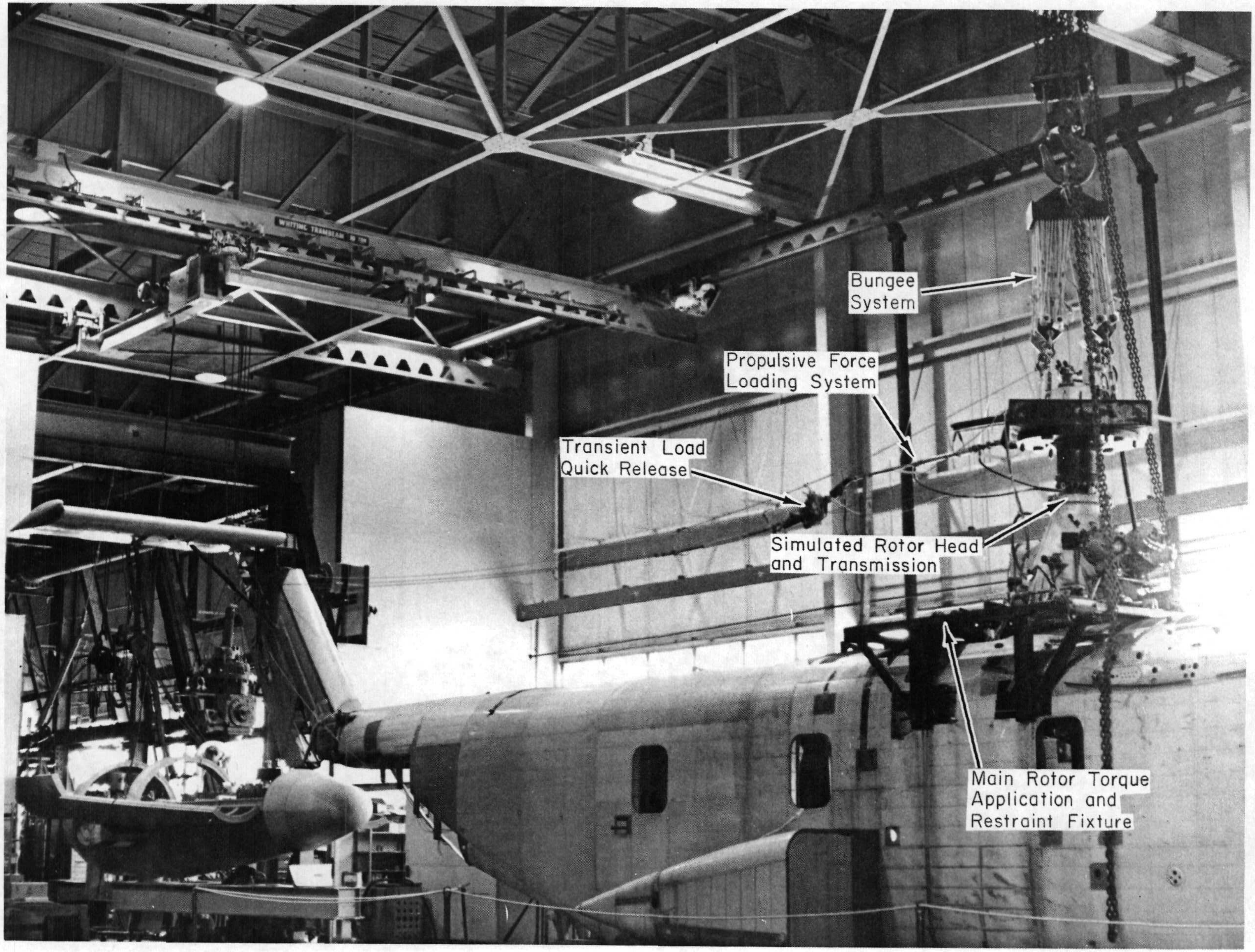

Figure 22. - Active Isolator/Rotor Force Measurement Test Facility.

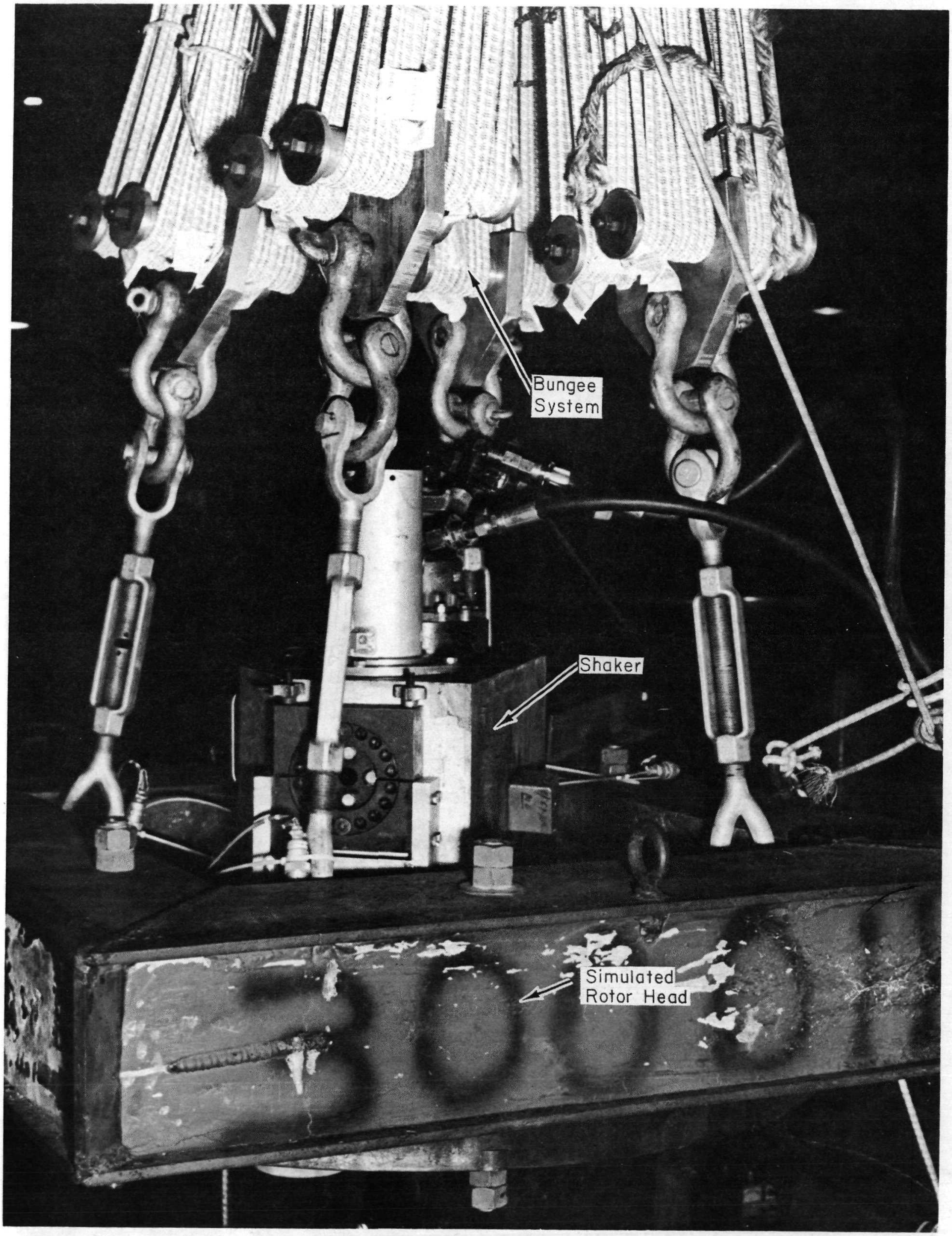

Figure 23. - Unidirectional Hydraulic Shaker Installation.

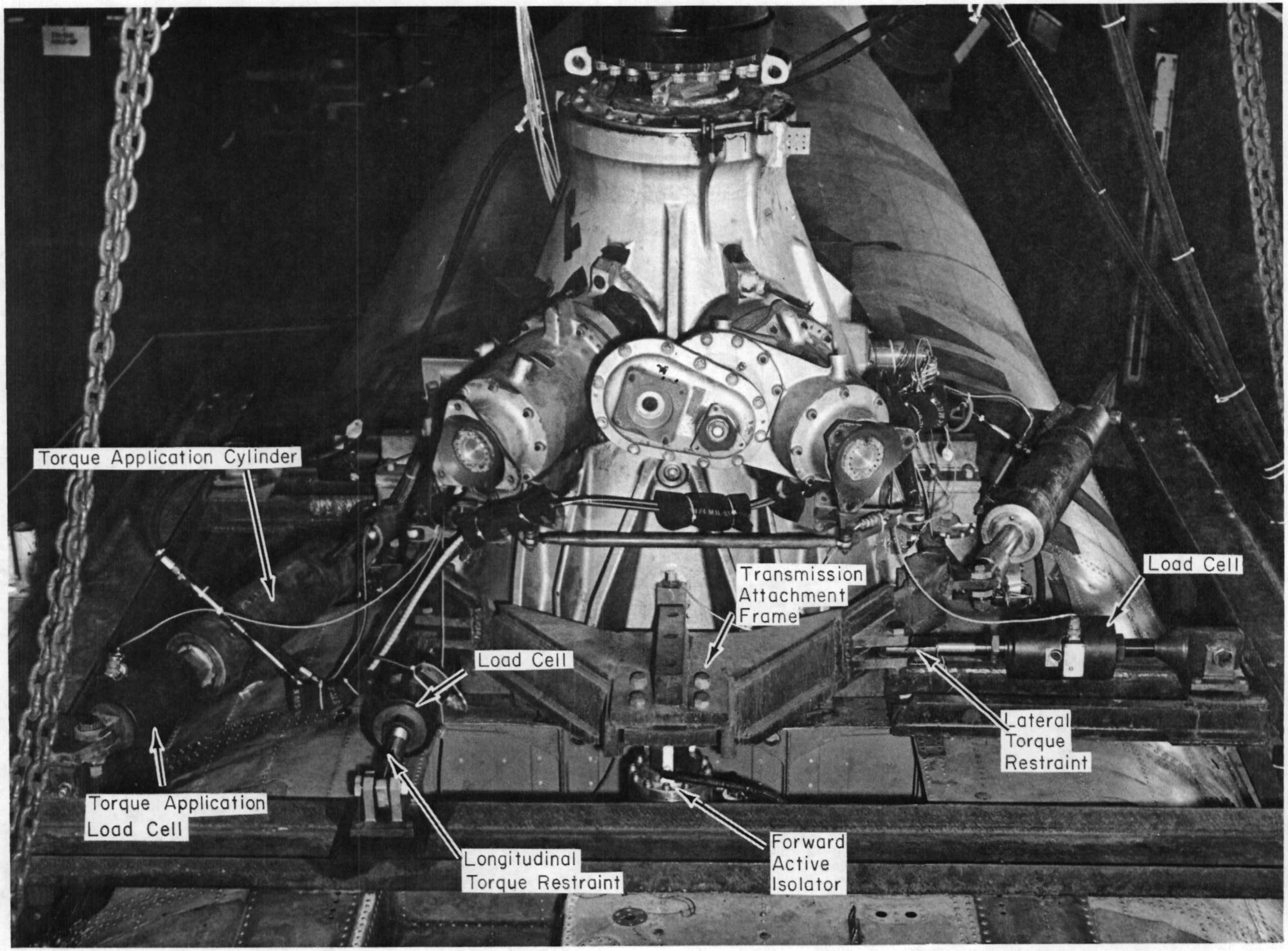

Figure 24. - Active Isolation Rotor Force Measurement System Installation.

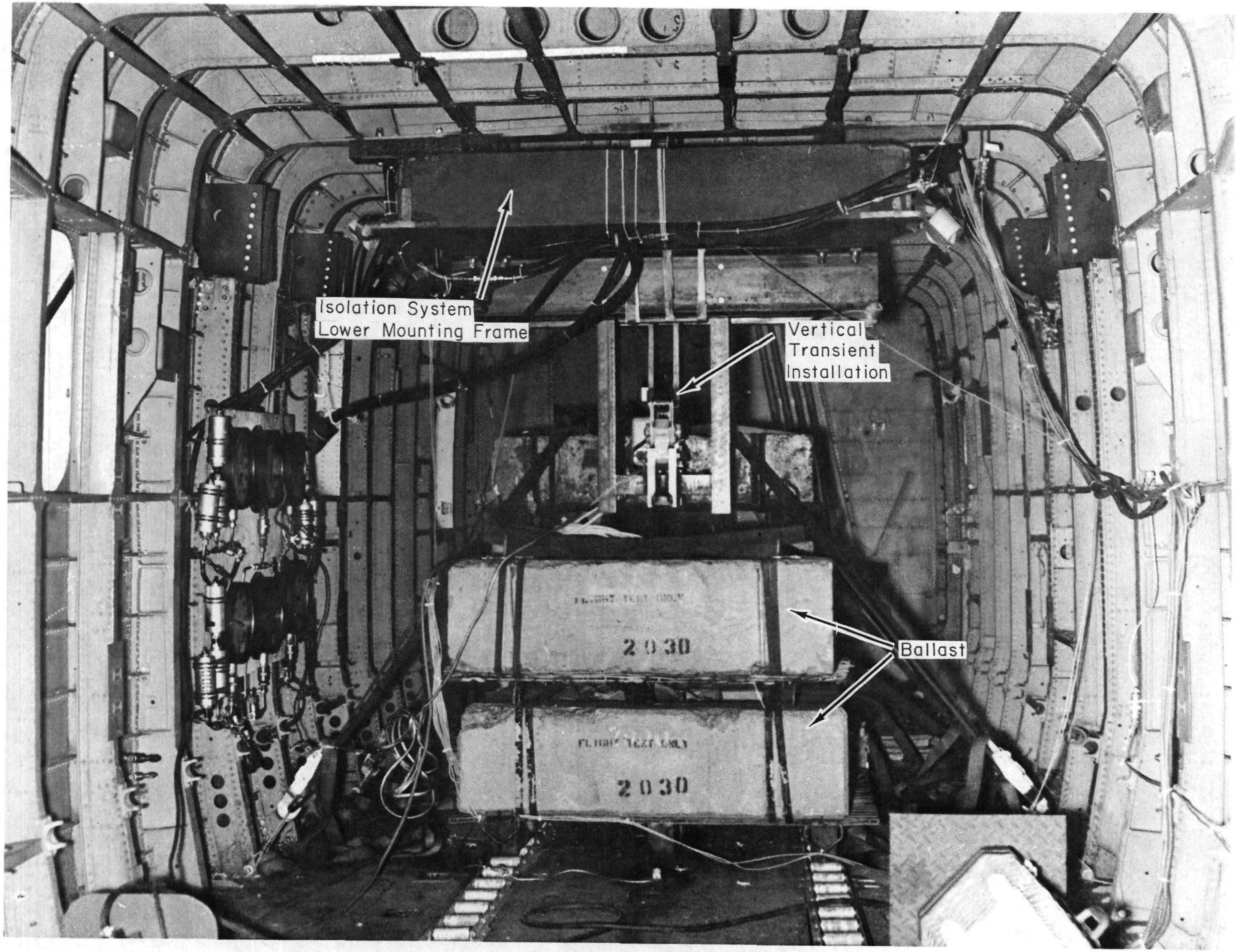

Figure 25. - Cabin Interior.

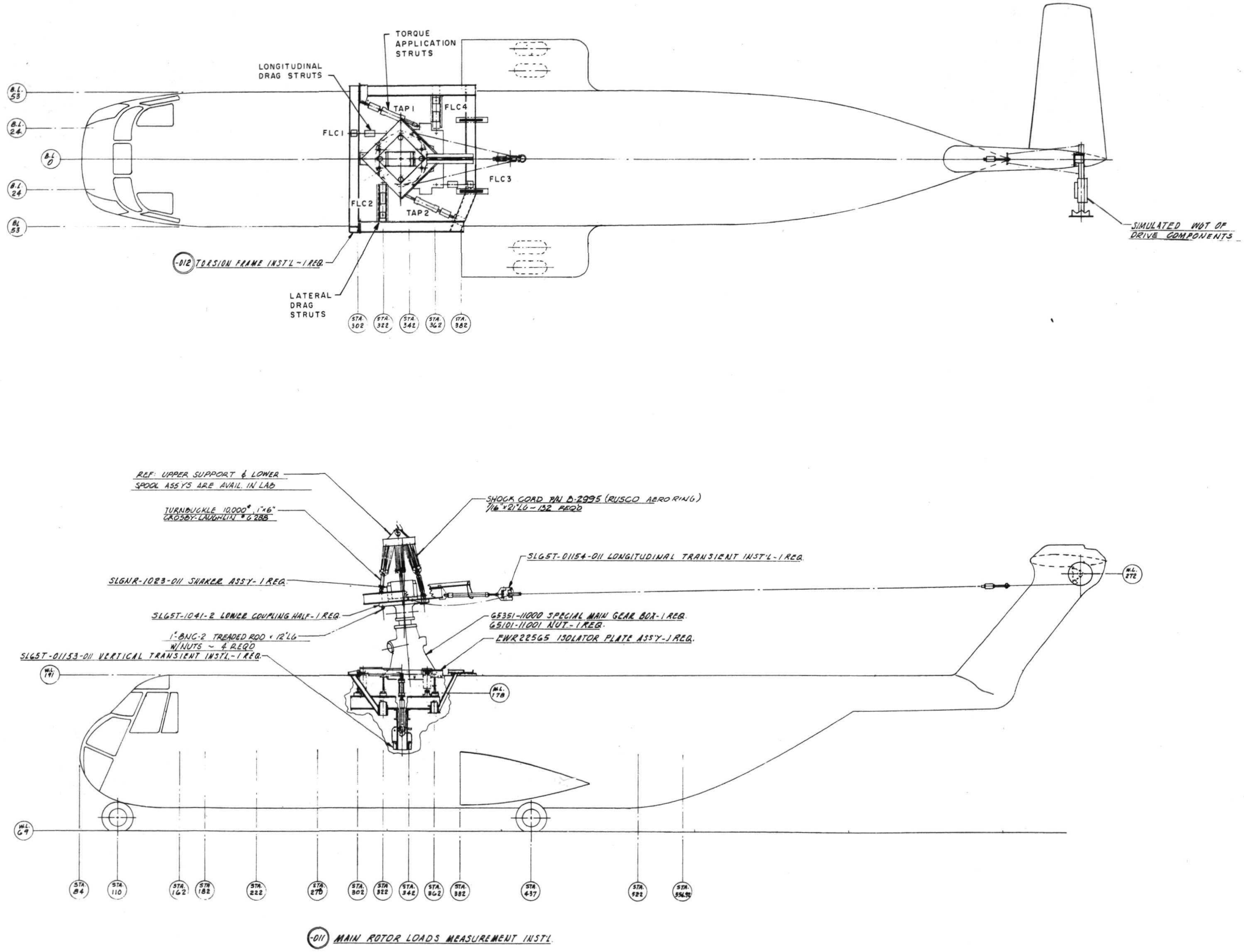

Figure 26. - Test Facility Illustration.

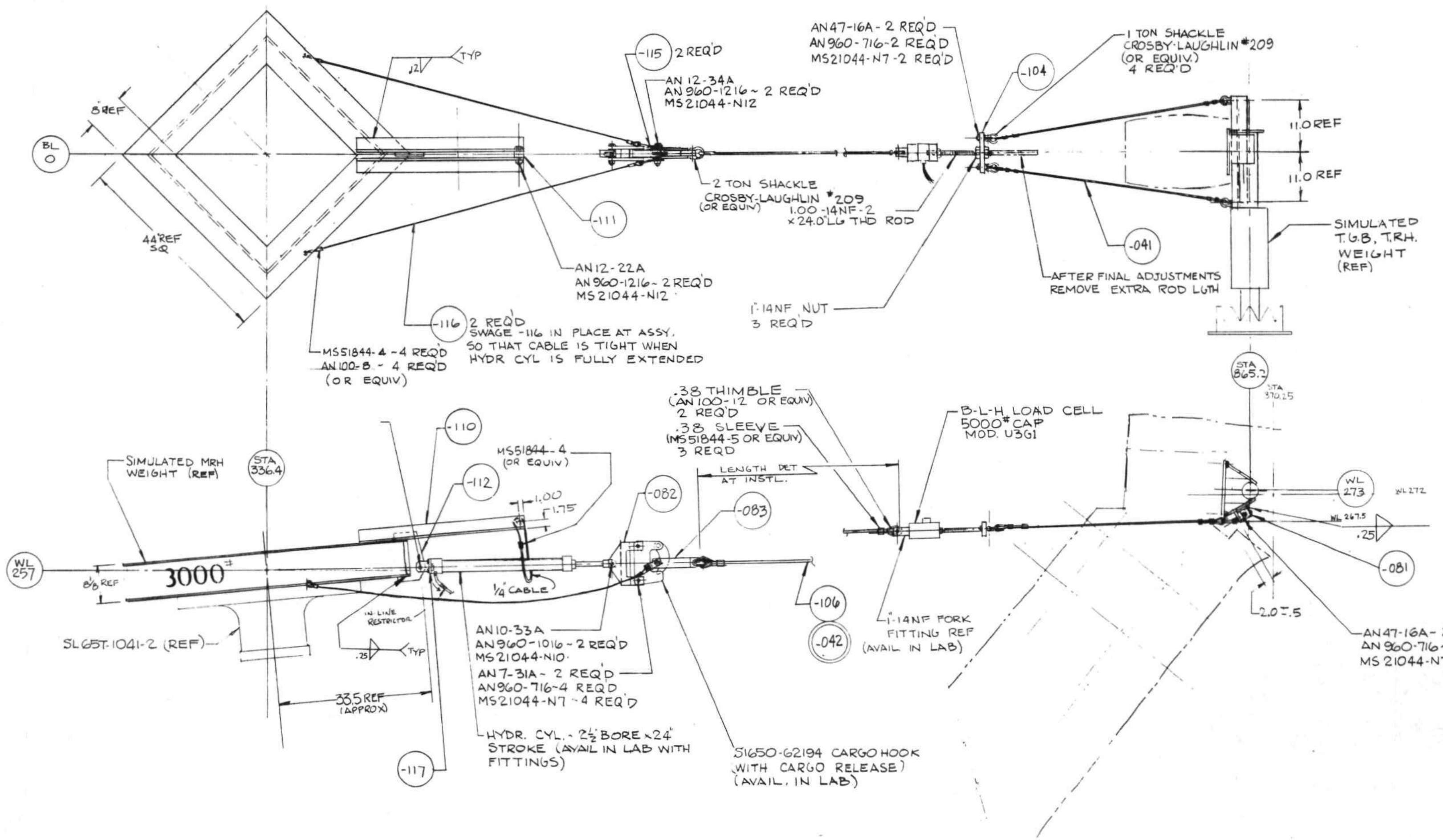

Figure 27. - Steady and Transient Propulsive Load Application System.

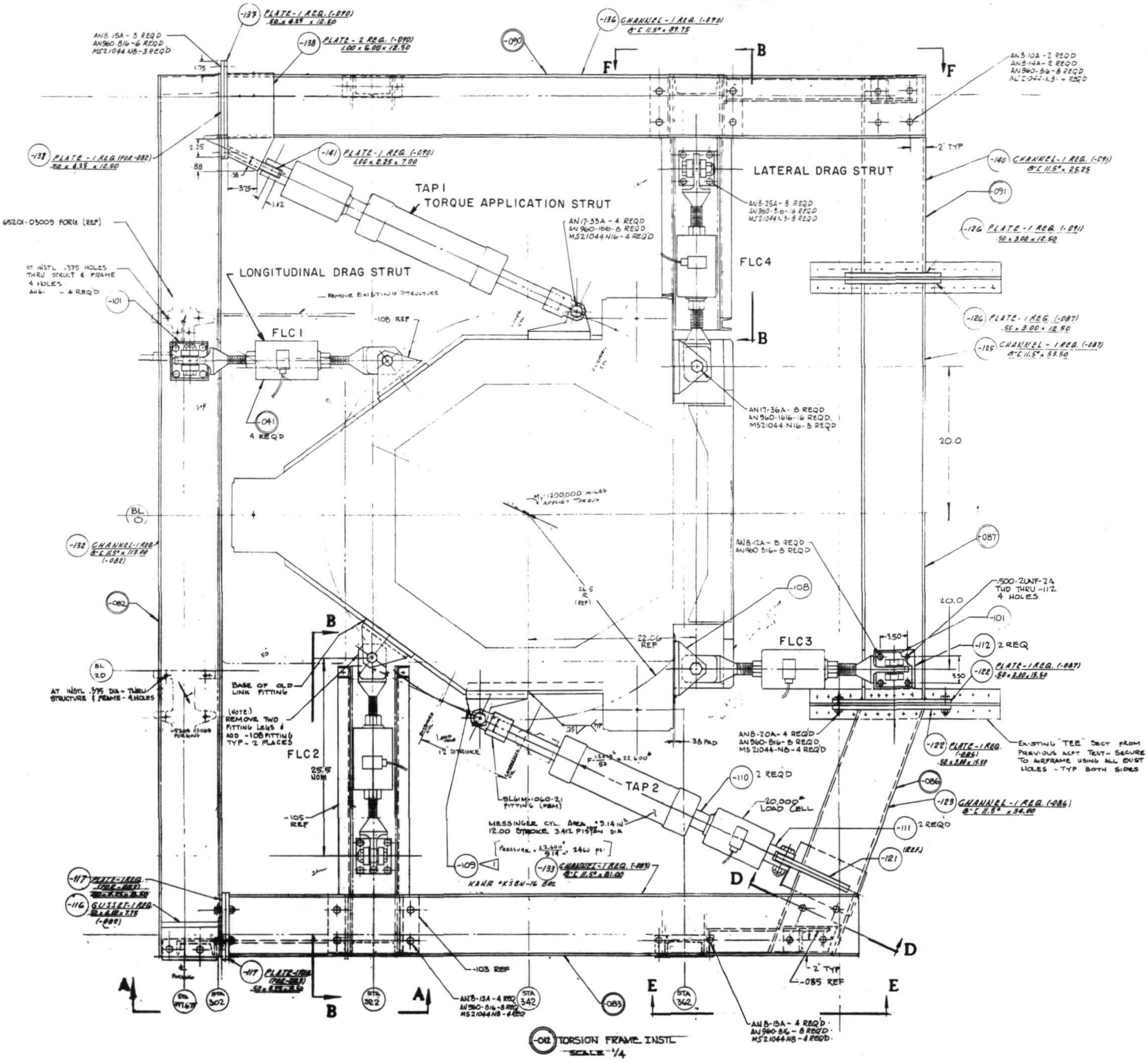

Figure 28. - Main Rotor Torque Application and Drag Strut Measuring Devices.

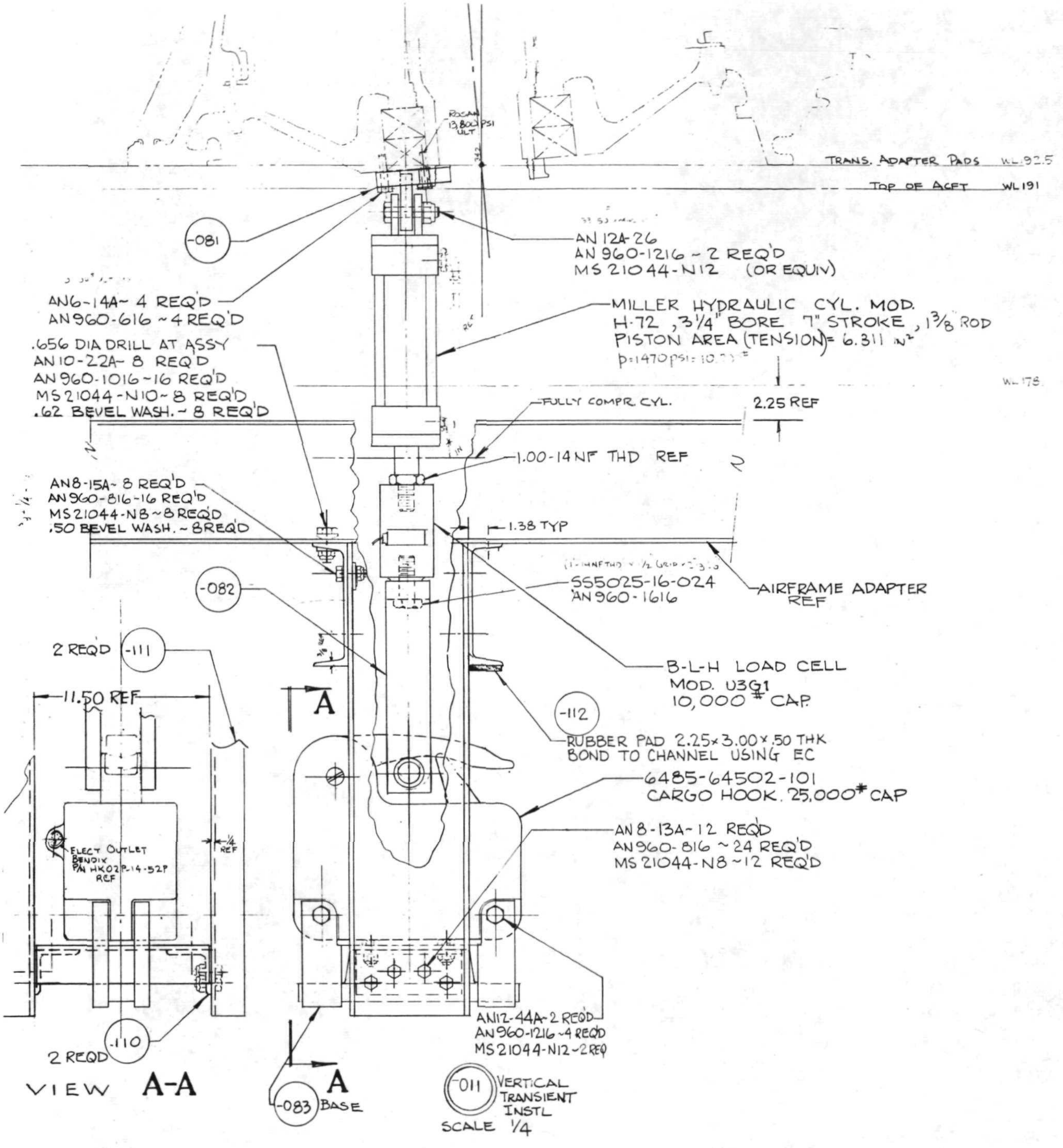

Figure 29. - Vertical Transient Loading System.

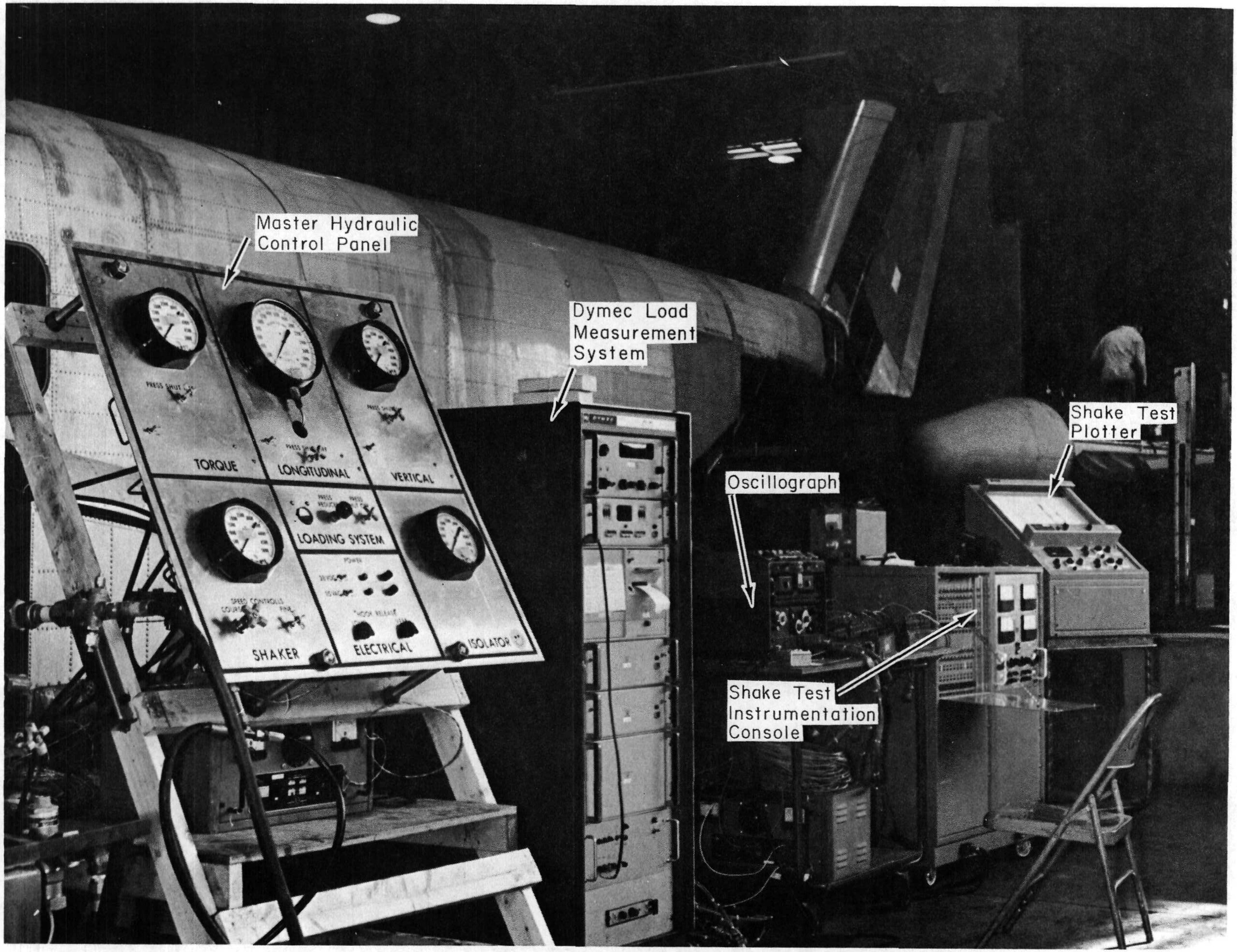

Figure 30. - Master Controls and Instrumentation for Steady and Vibratory Loads.

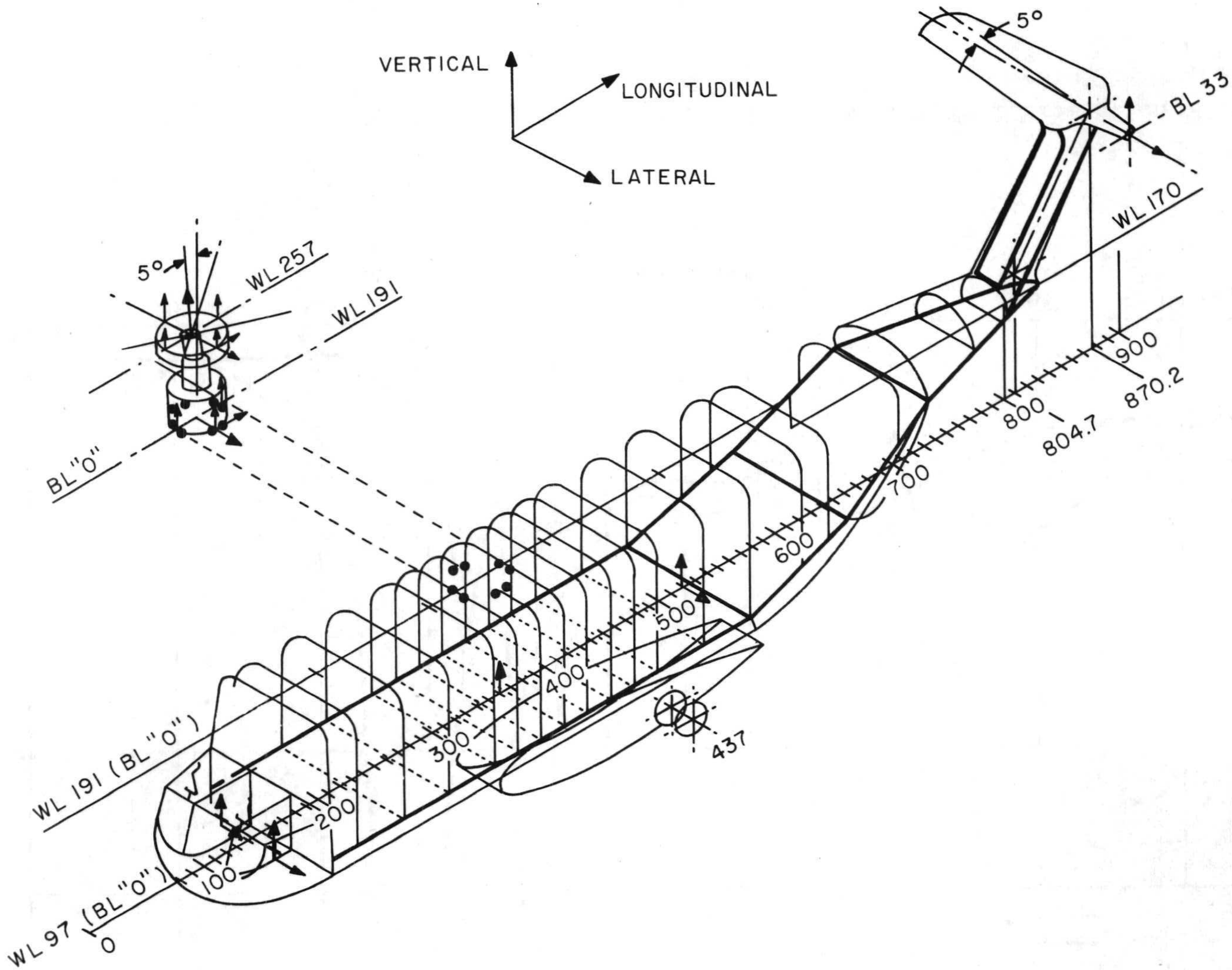

Figure 31. - Accelerometer Locations.

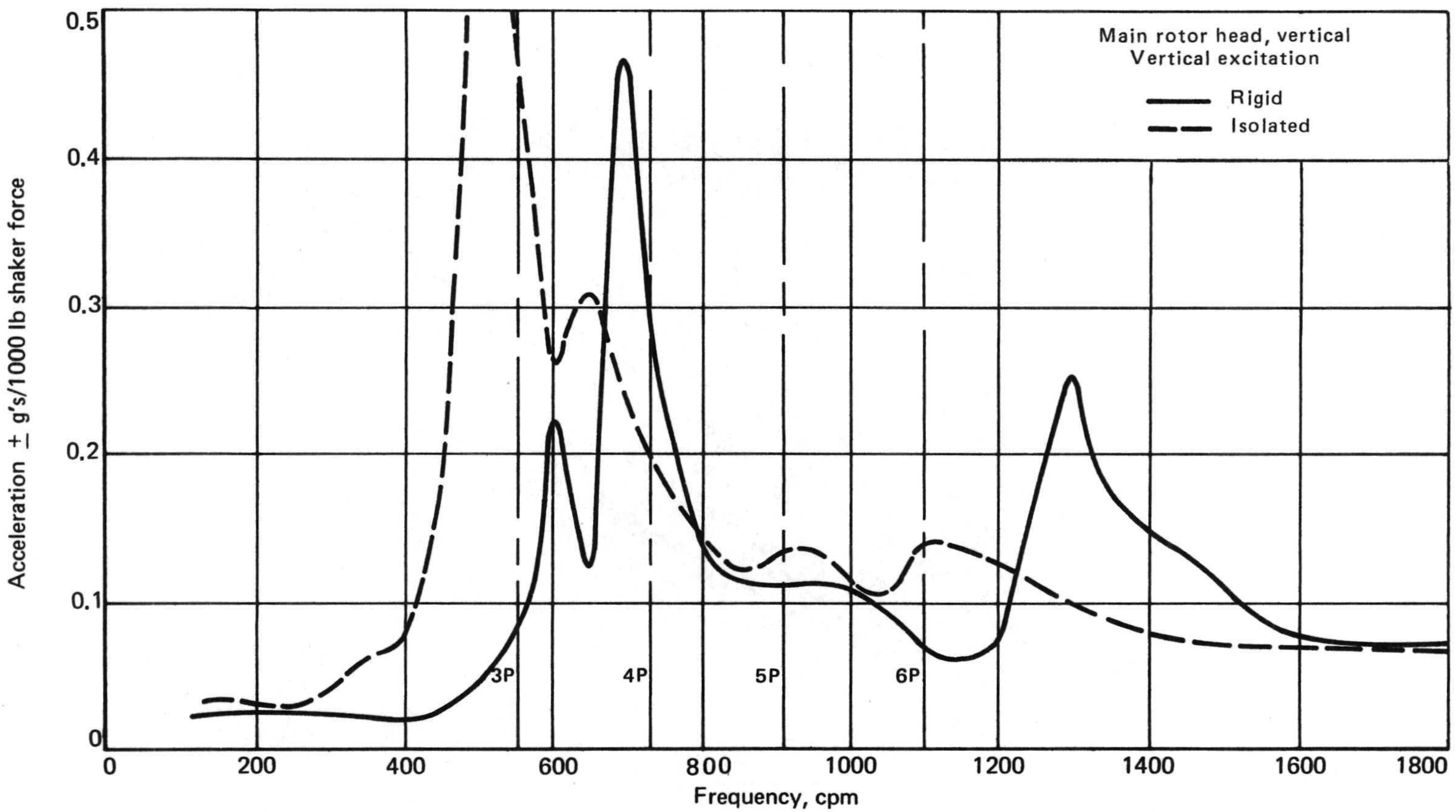

Figure 32. - Main Rotor Head-Vertical Response due to Vertical Excitation.

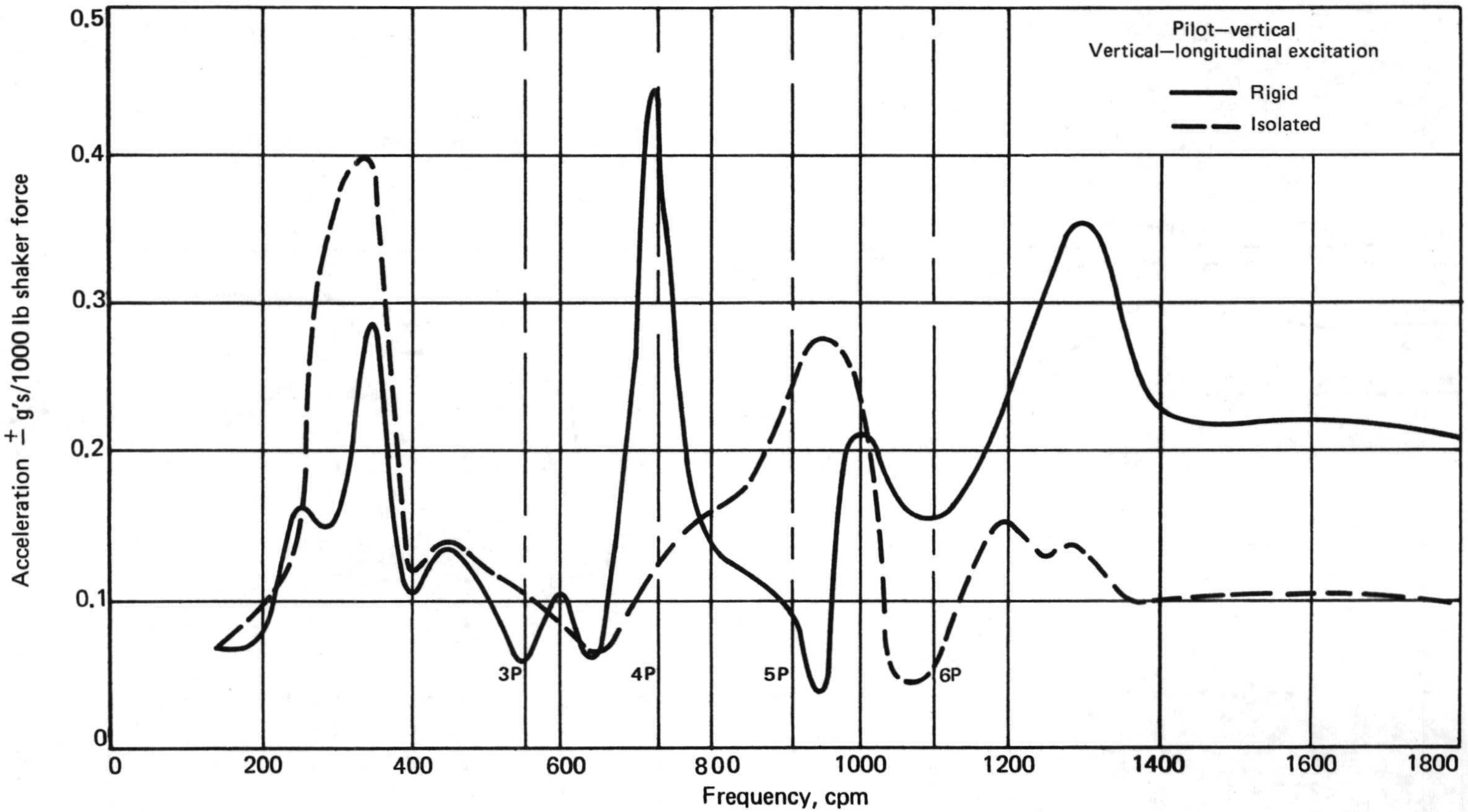

Figure 33. - Pilot Vertical Response due to Vertical-Longitudinal Excitation

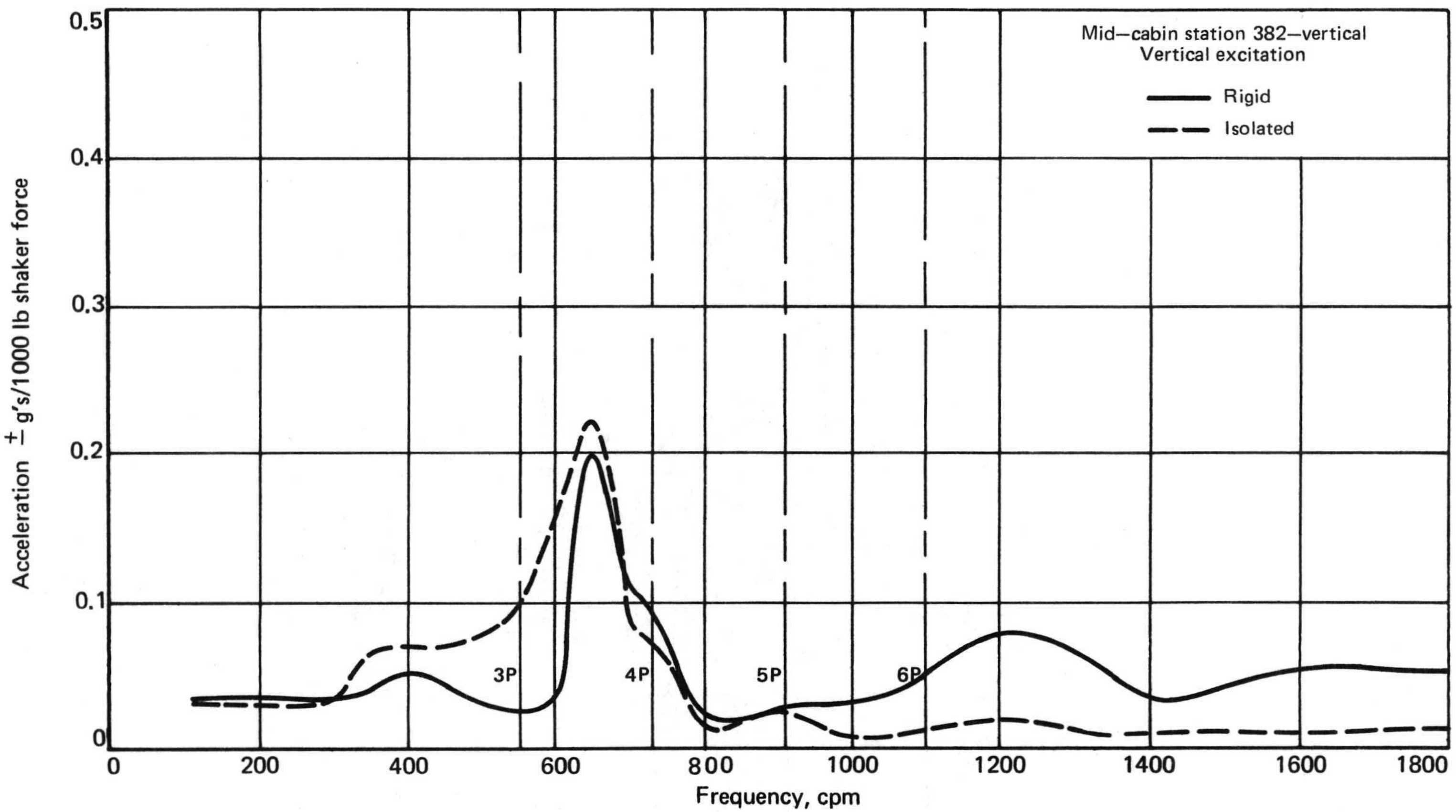

Figure 34. - Mid Cabin Vertical Response Due to Vertical Excitation.

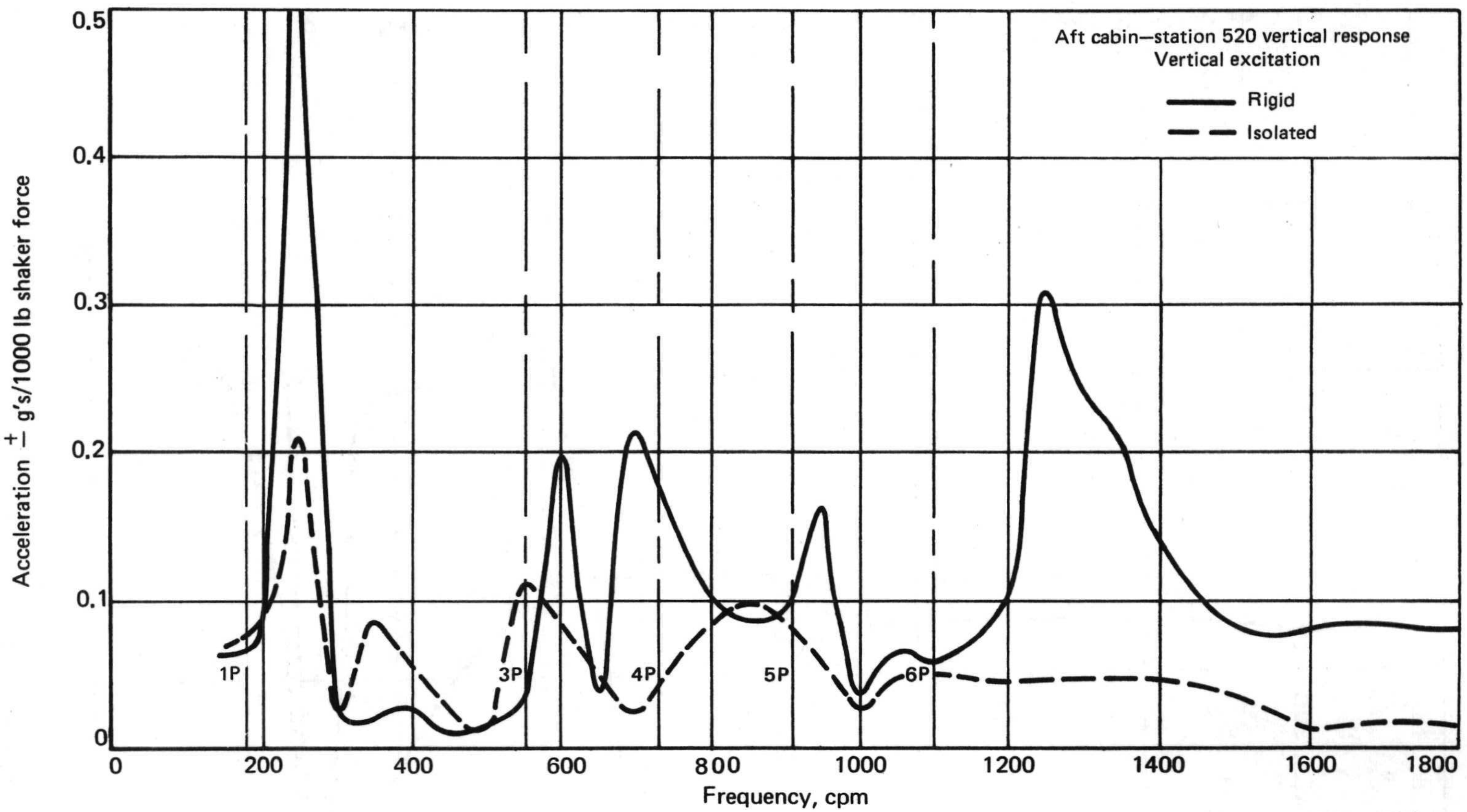

Figure 35. - Aft Cabin Vertical Response Due to Vertical Excitation.

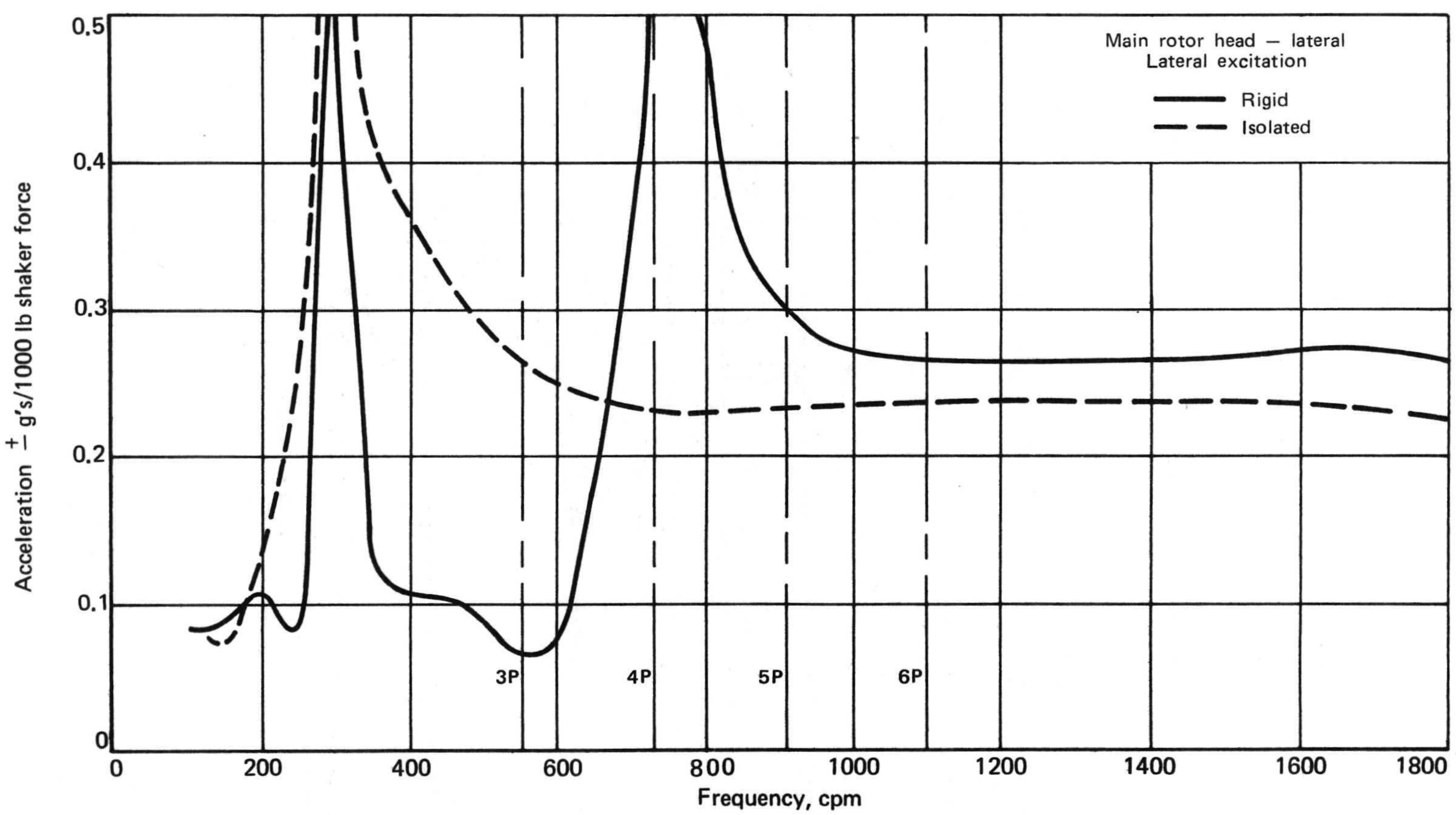

Figure 36. - Main Rotor Head-Lateral Response Due to Lateral Excitation.

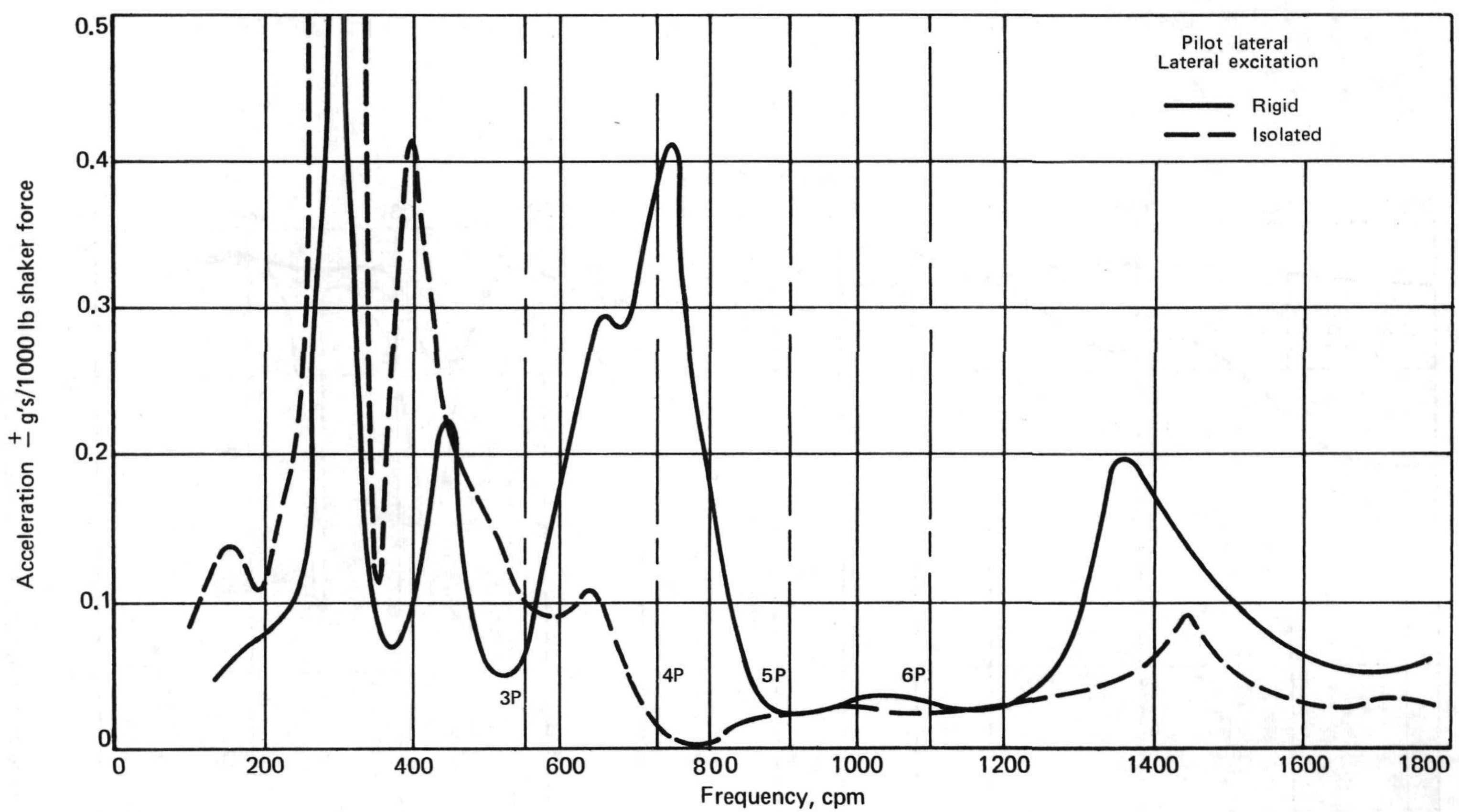

Figure 37. - Pilot Head-Lateral Response Due to Lateral Excitation.

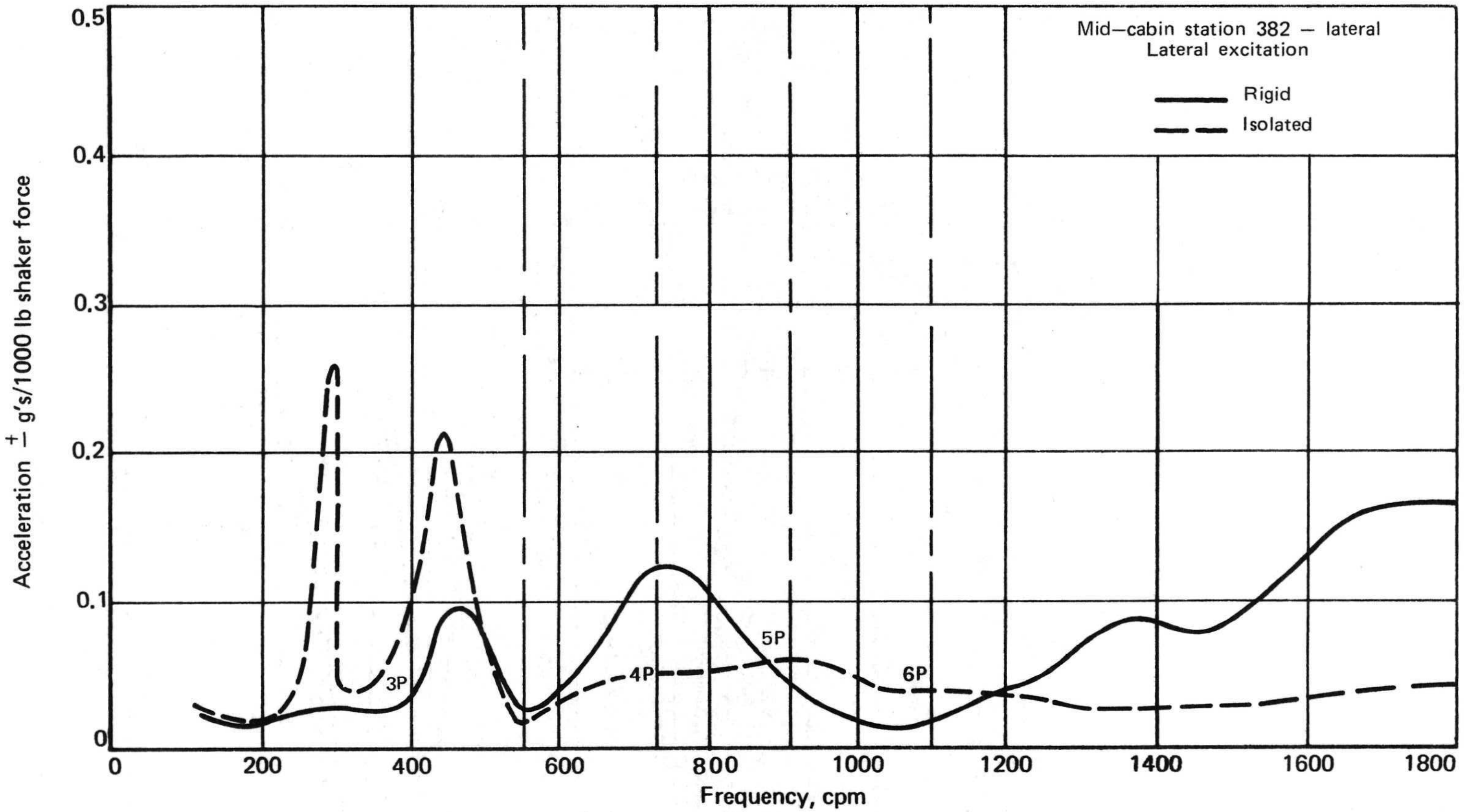

Figure 38. - Mid Cabin Head-Lateral Response Due to Lateral Excitation.

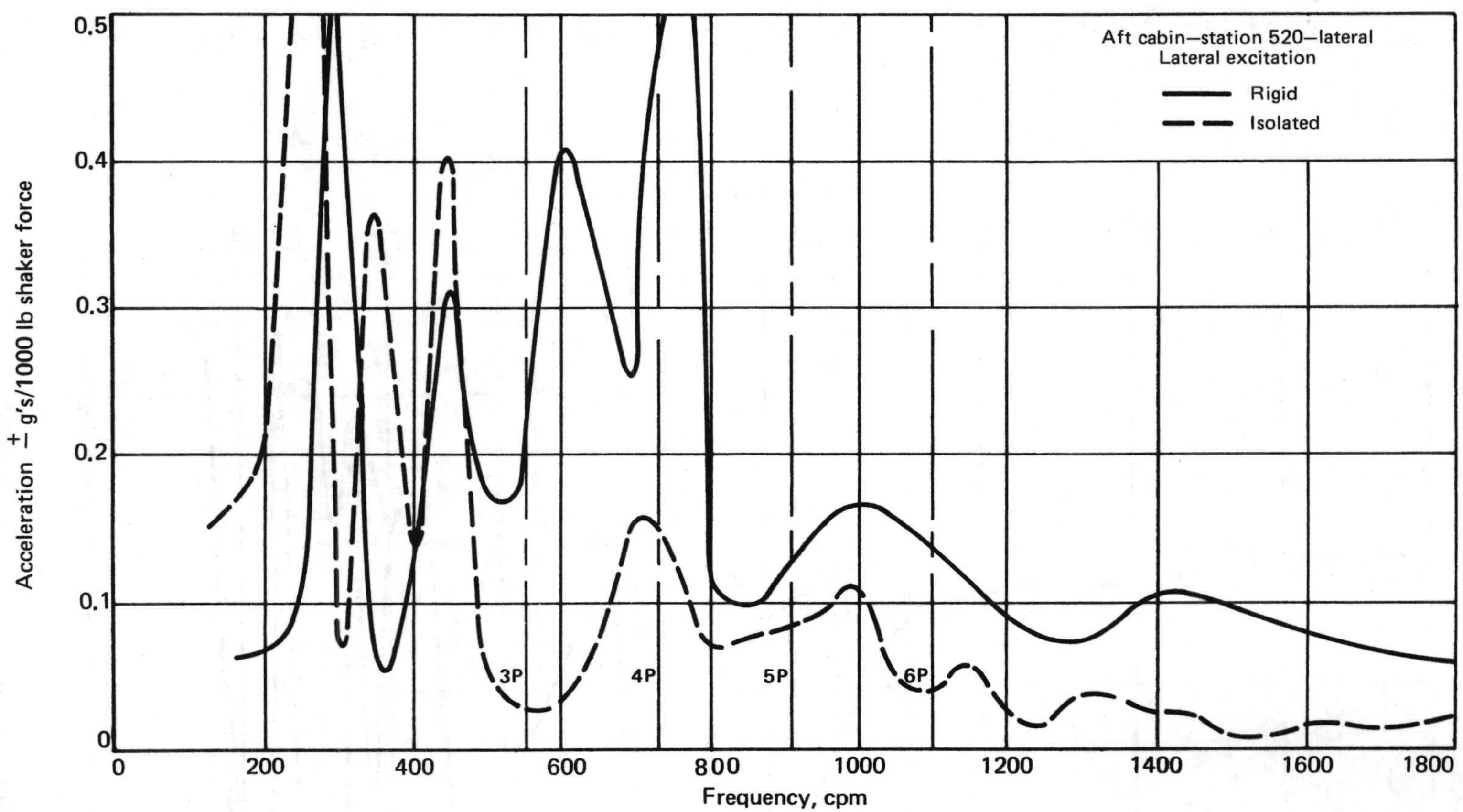

Figure 39. - Aft Cabin Head-Lateral Response due to Lateral Excitation.

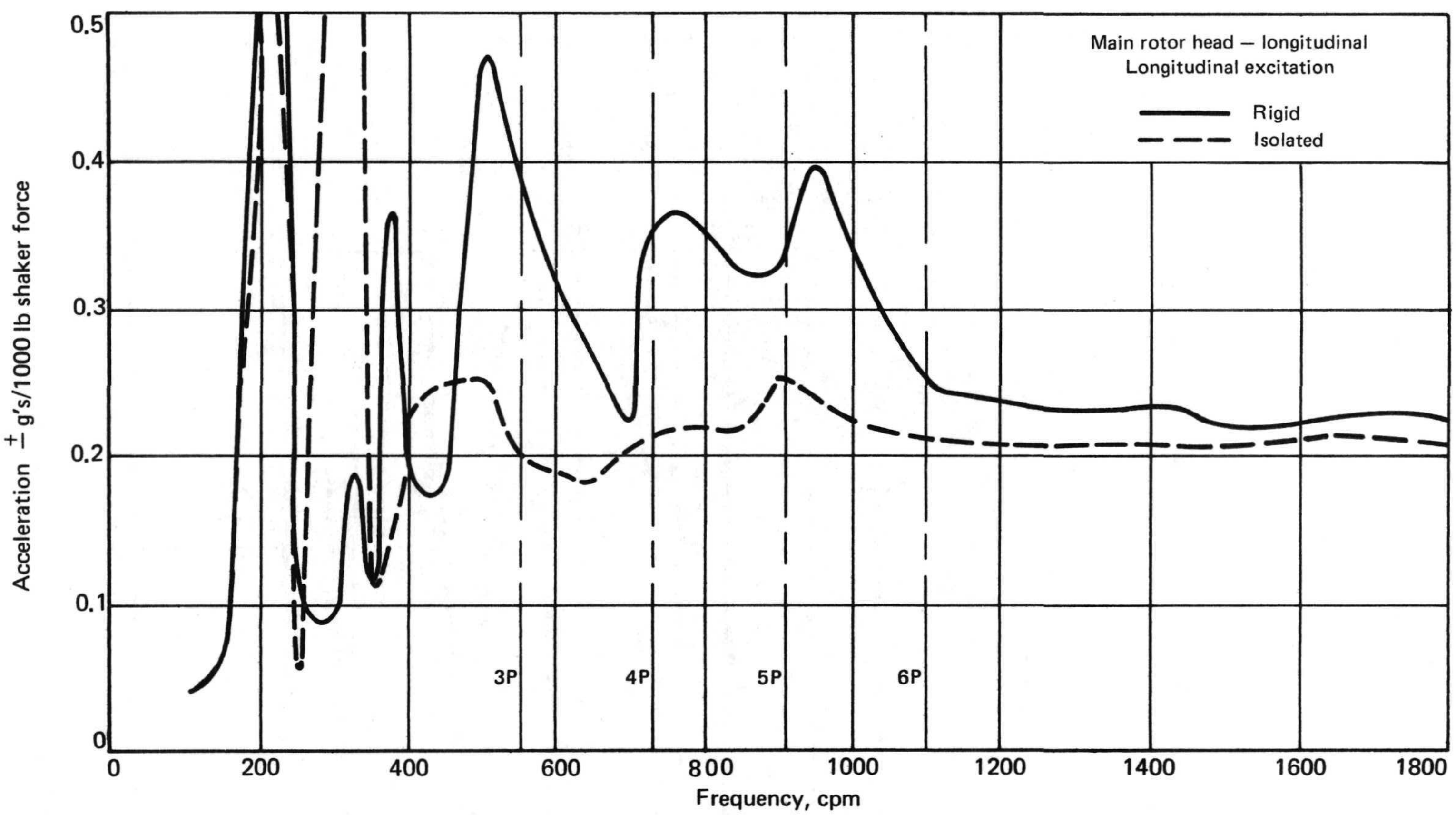

Figure 40. - Main Rotor Head-Longitudinal Response Due to Longitudinal Excitation

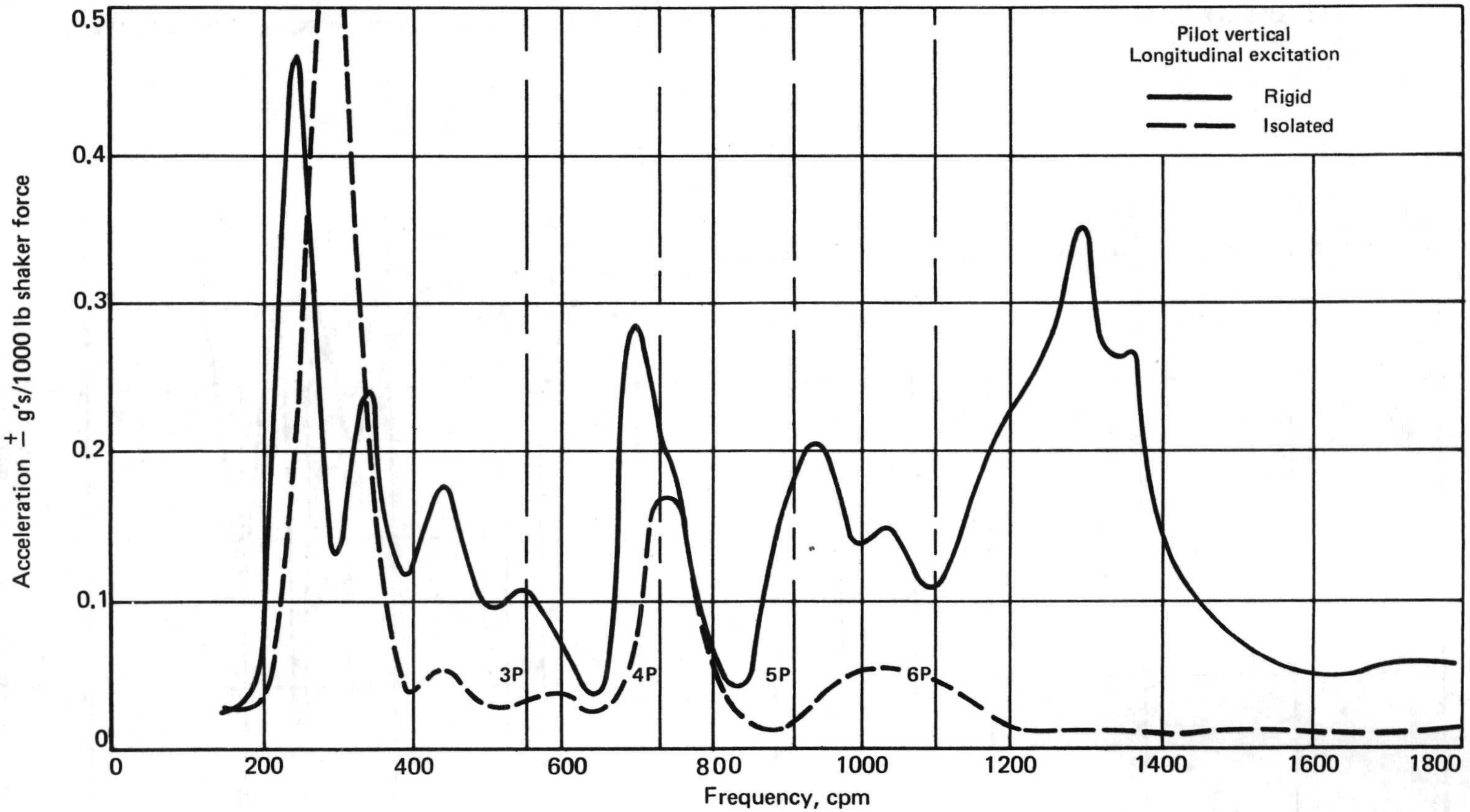

Figure 41. - Pilot Head-Longitudinal Response Due to Longitudinal Excitation.

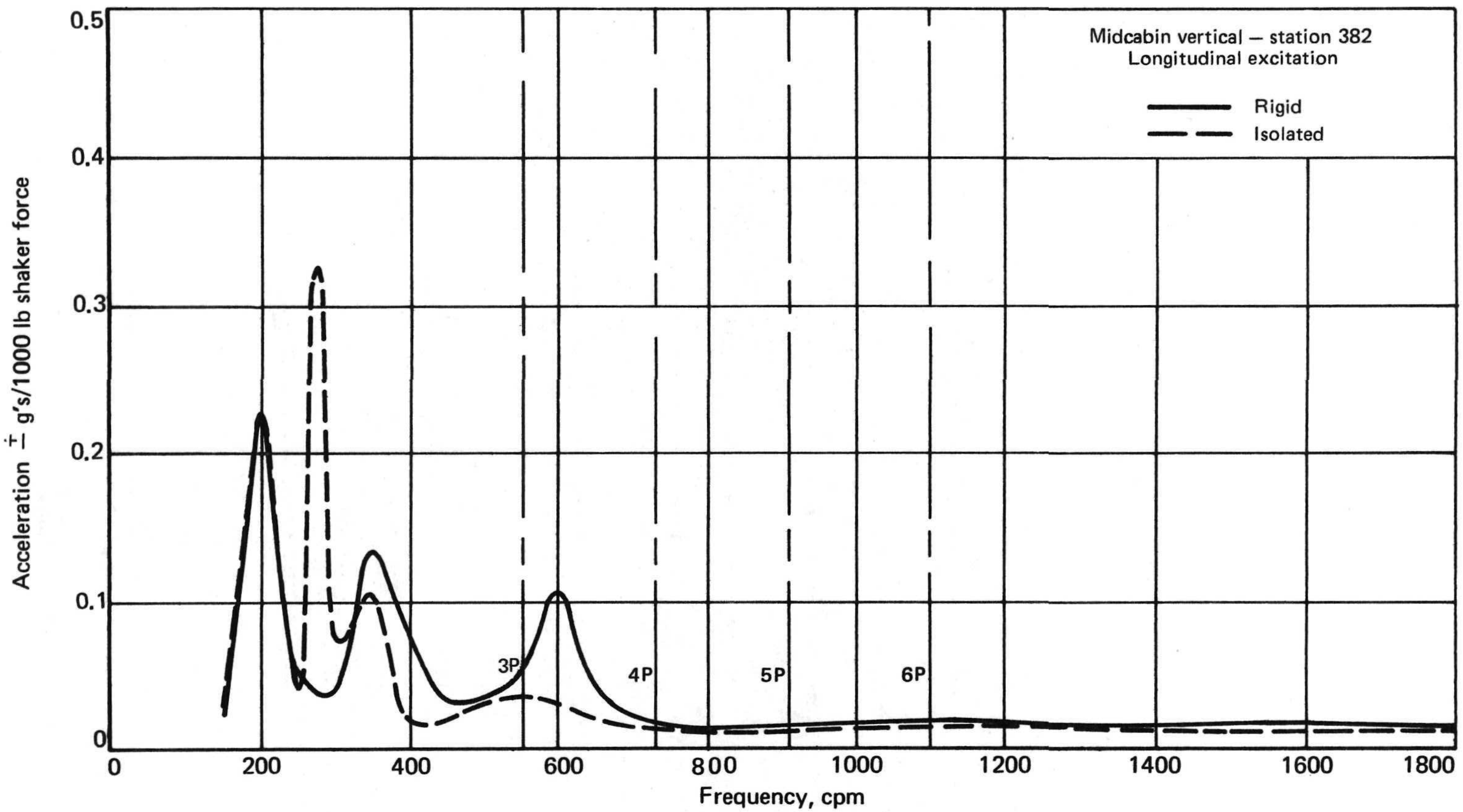

Figure 42. - Mid Cabin Head-Longitudinal Response Due to Longitudinal Excitation.

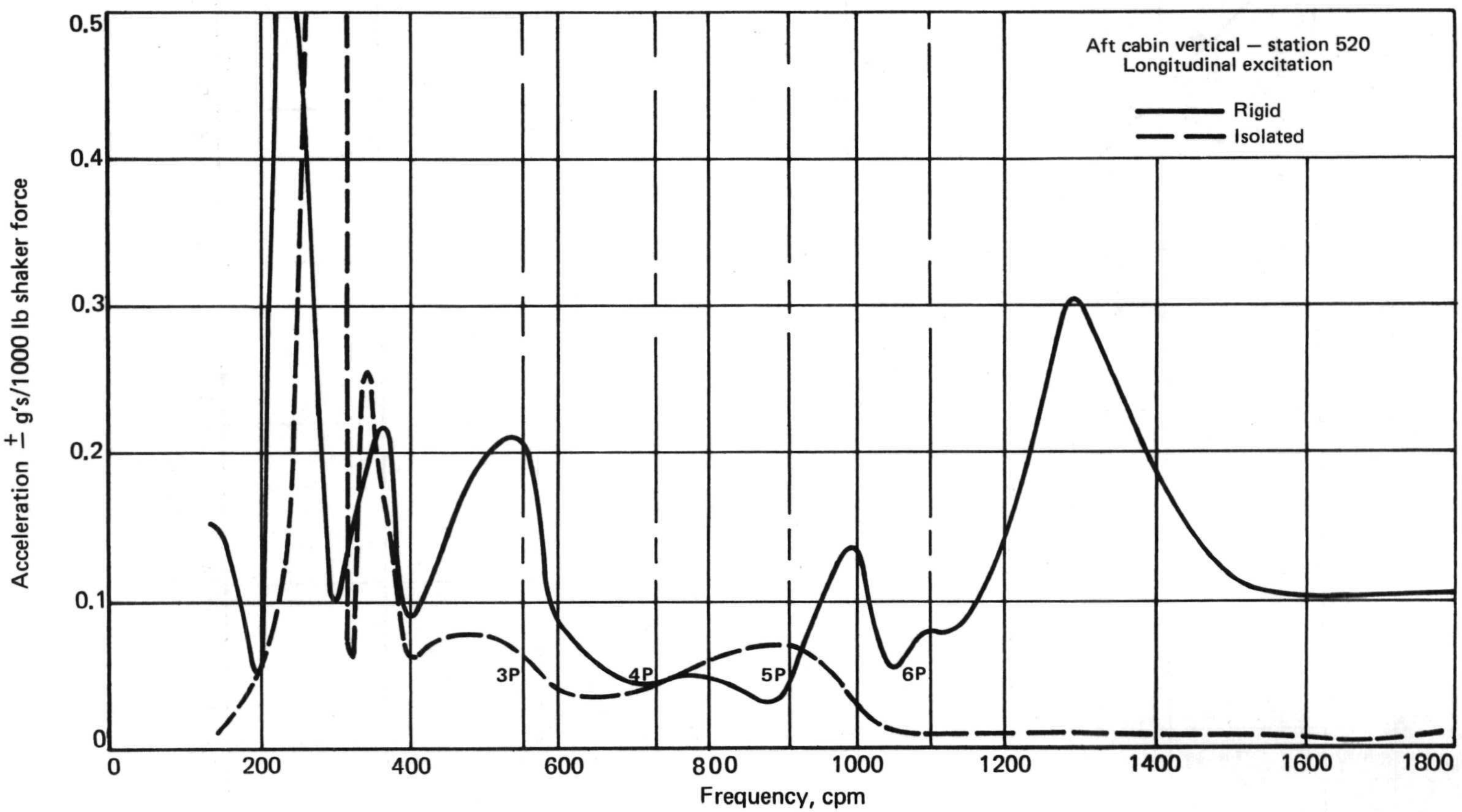

Figure 43. - Aft Cabin Head-Longitudinal Response Due to Longitudinal Excitation.

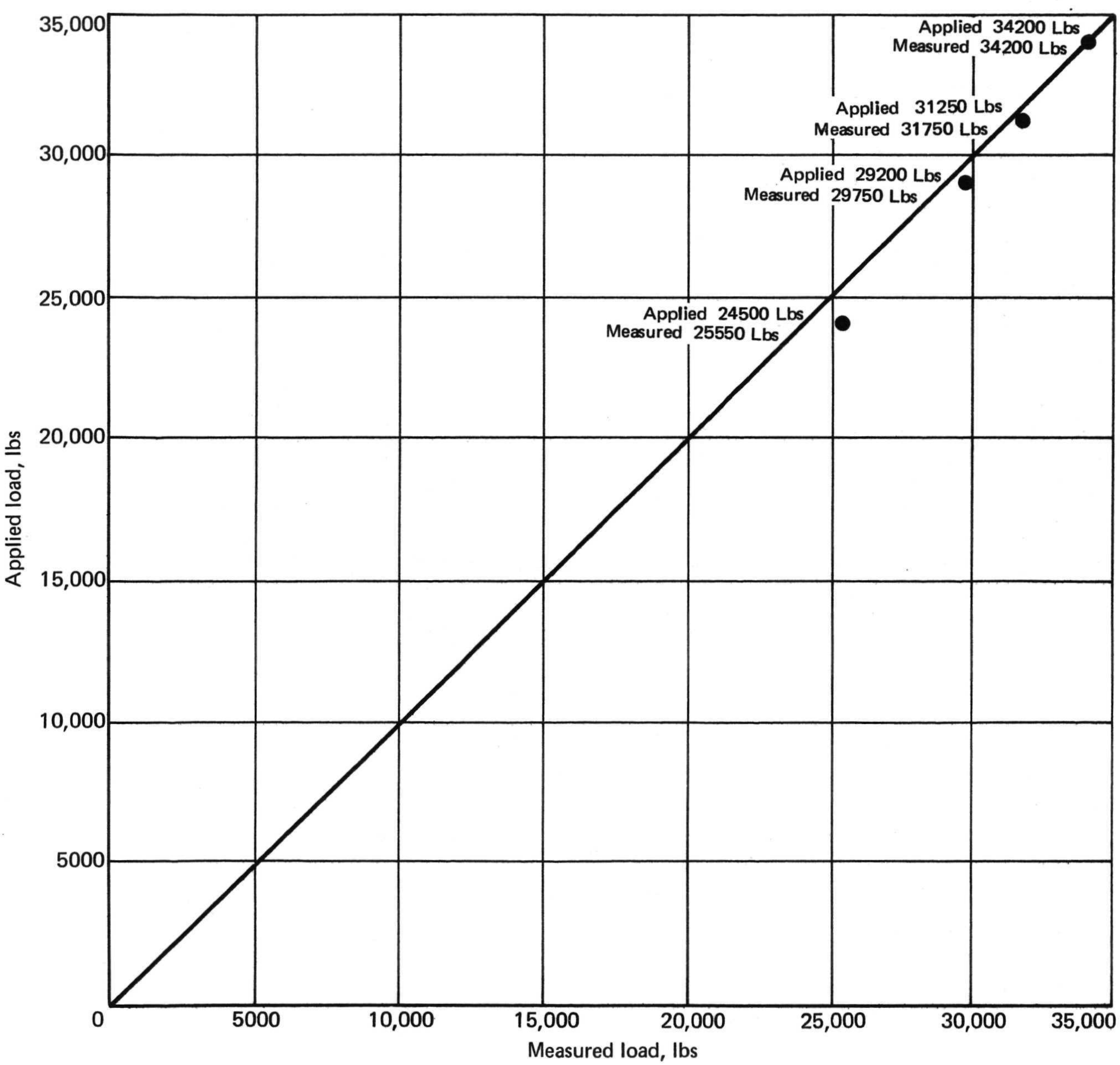

Figure 44. - Rotor Lift Calibration.

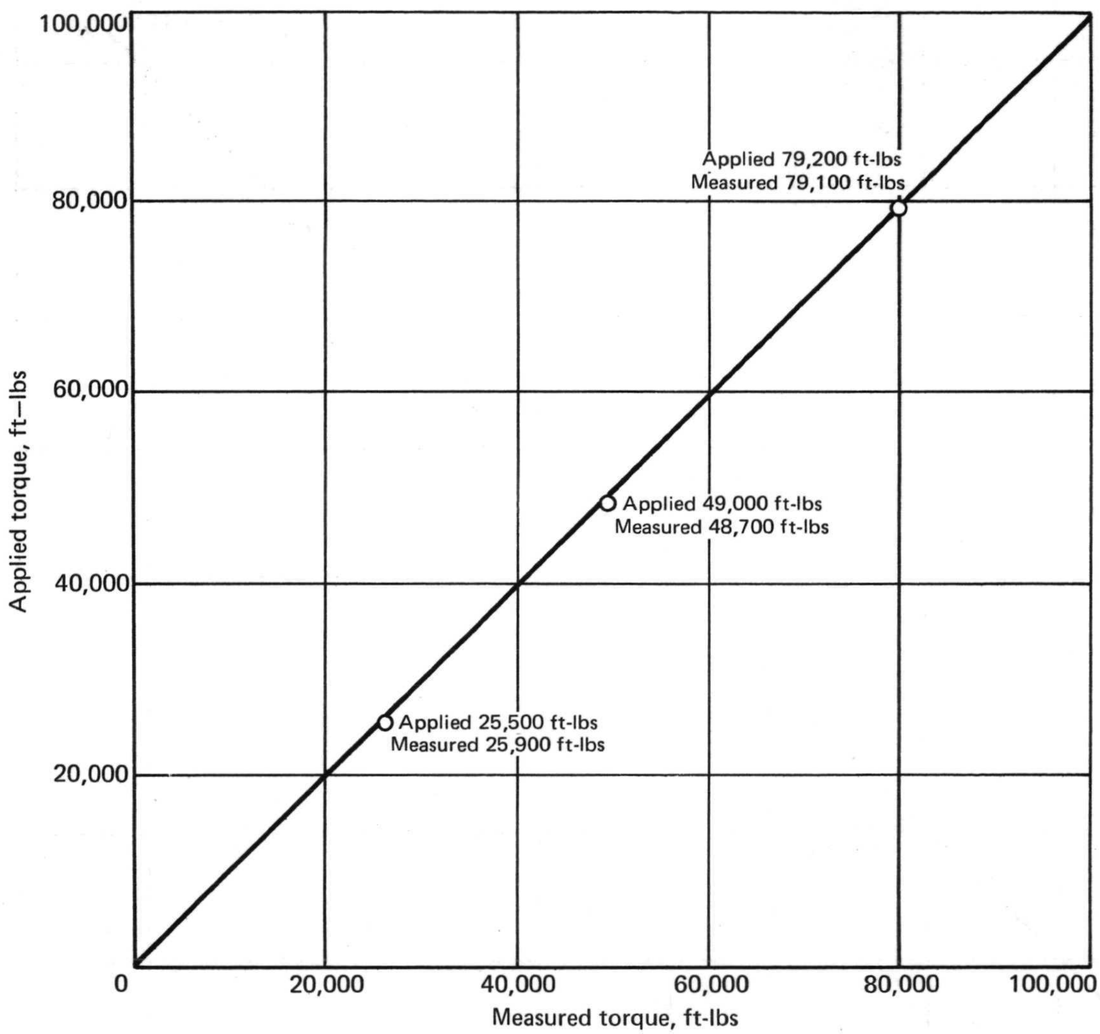

Figure 45. - Main Rotor Torque Calibration.

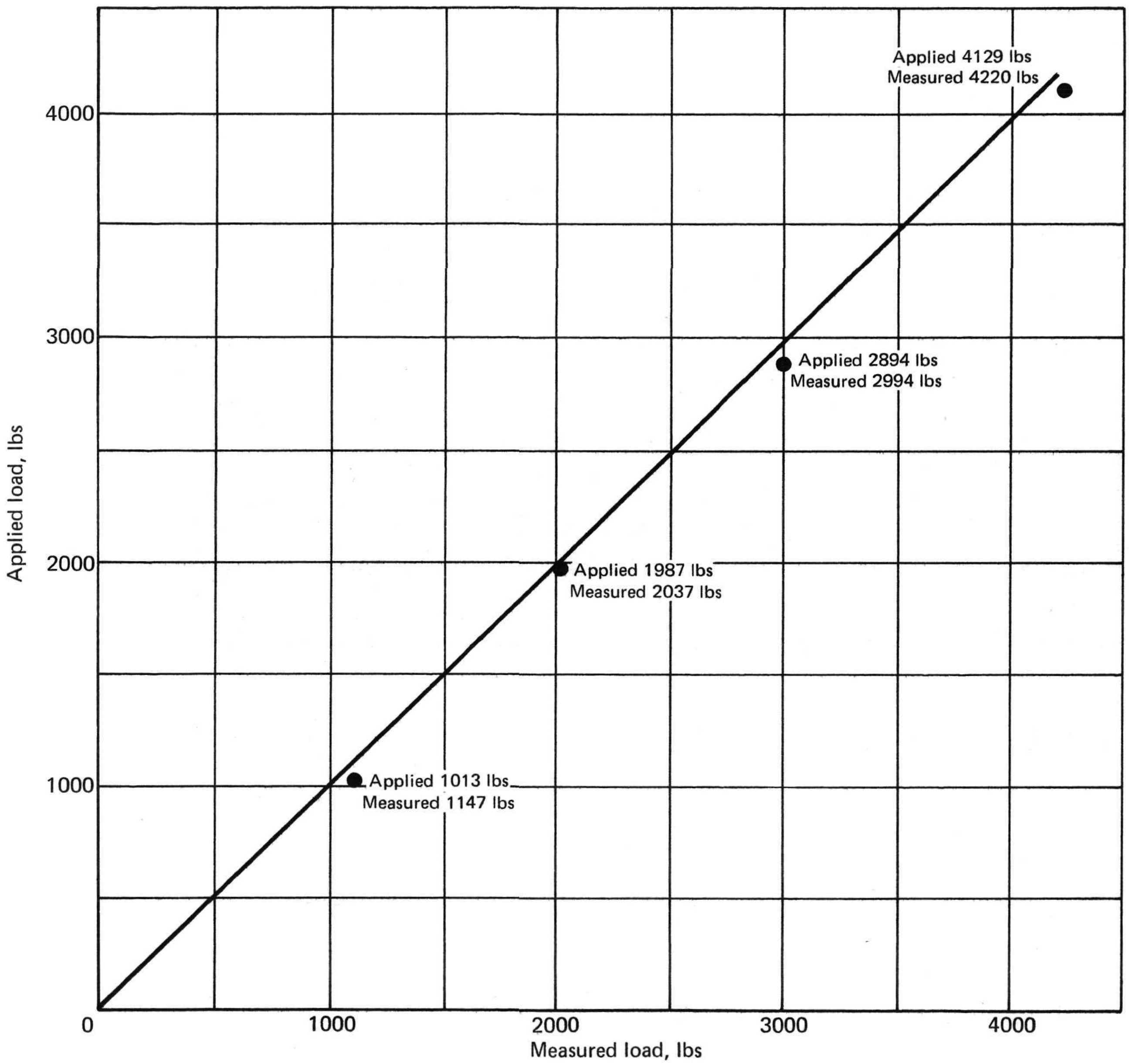

Figure 46. - Propulsive Force Calibration.

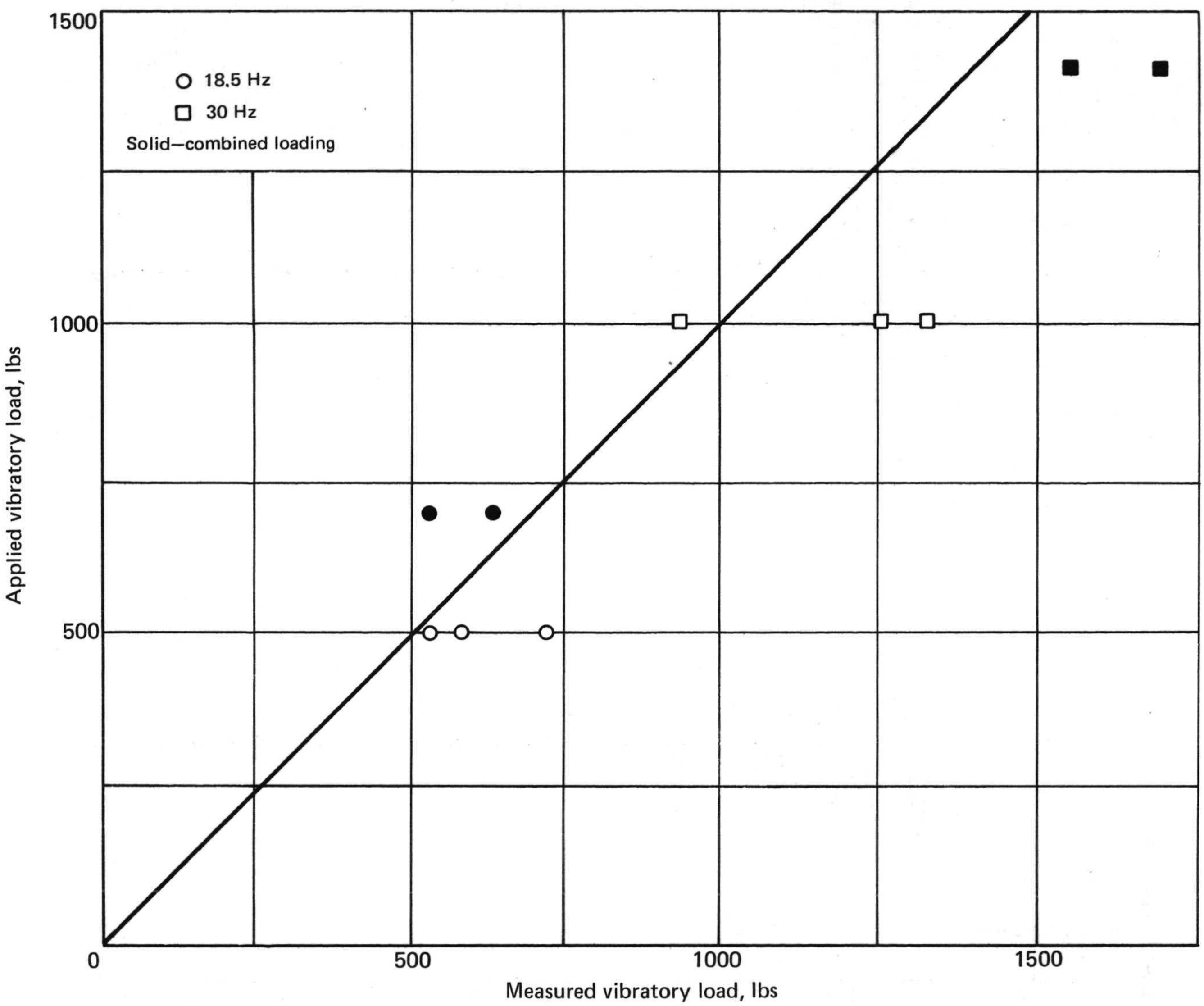

Figure 47. - Total Isolated Vibratory Load Calibration.

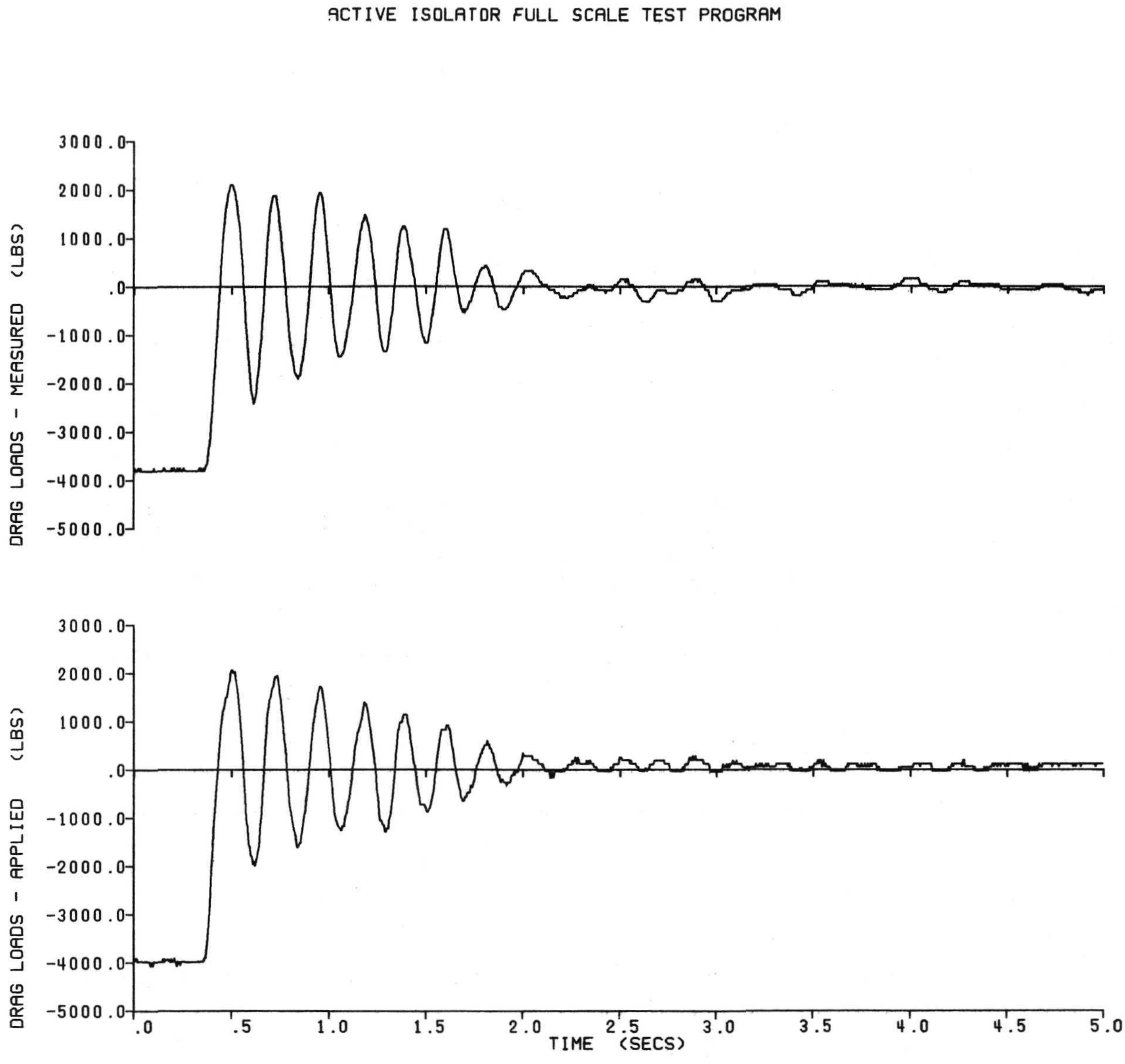

Figure 48. - Longitudinal Transient Response.

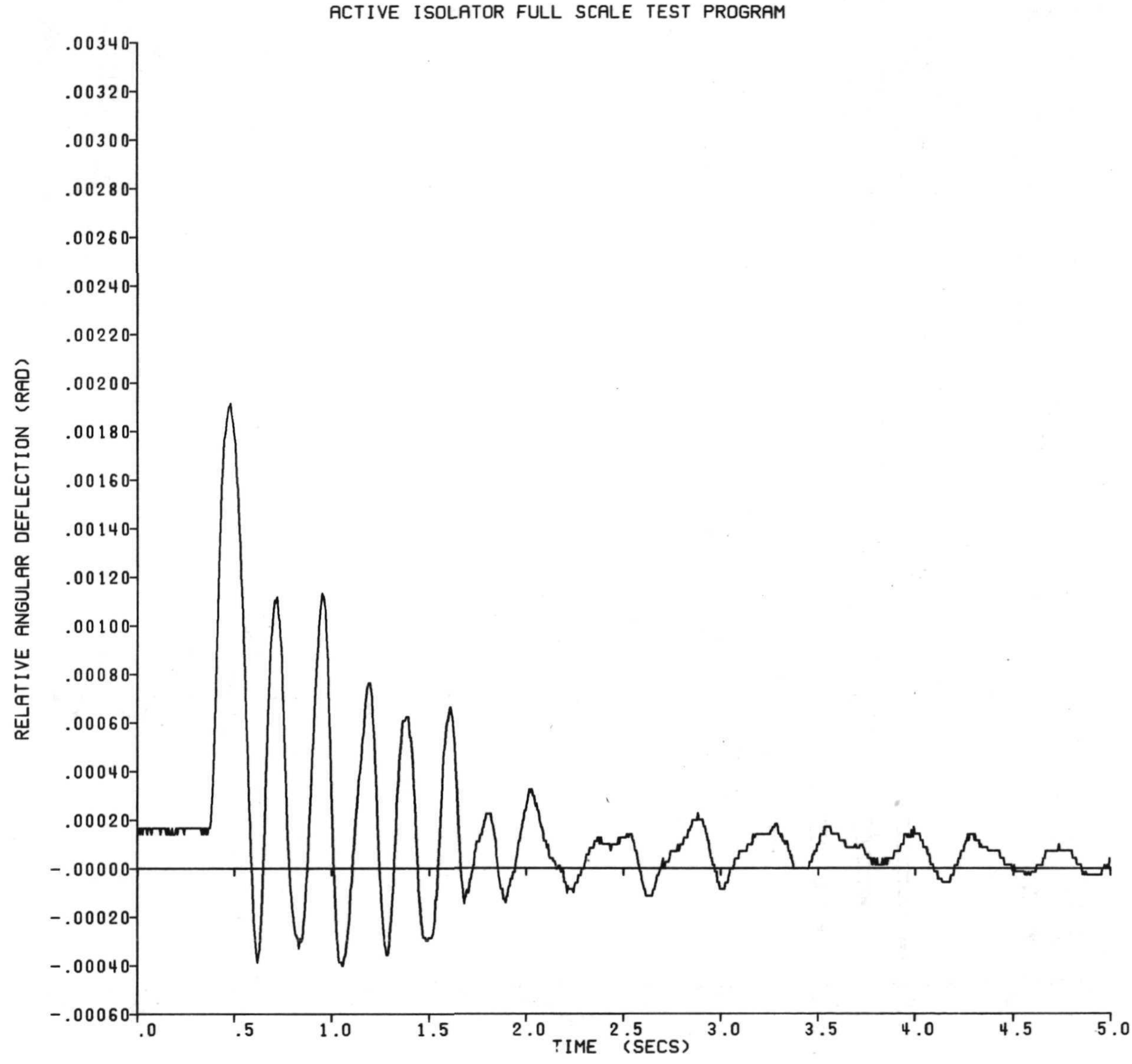

Figure 49. - Angular Deflection Between Airframe and Transmission Interface.

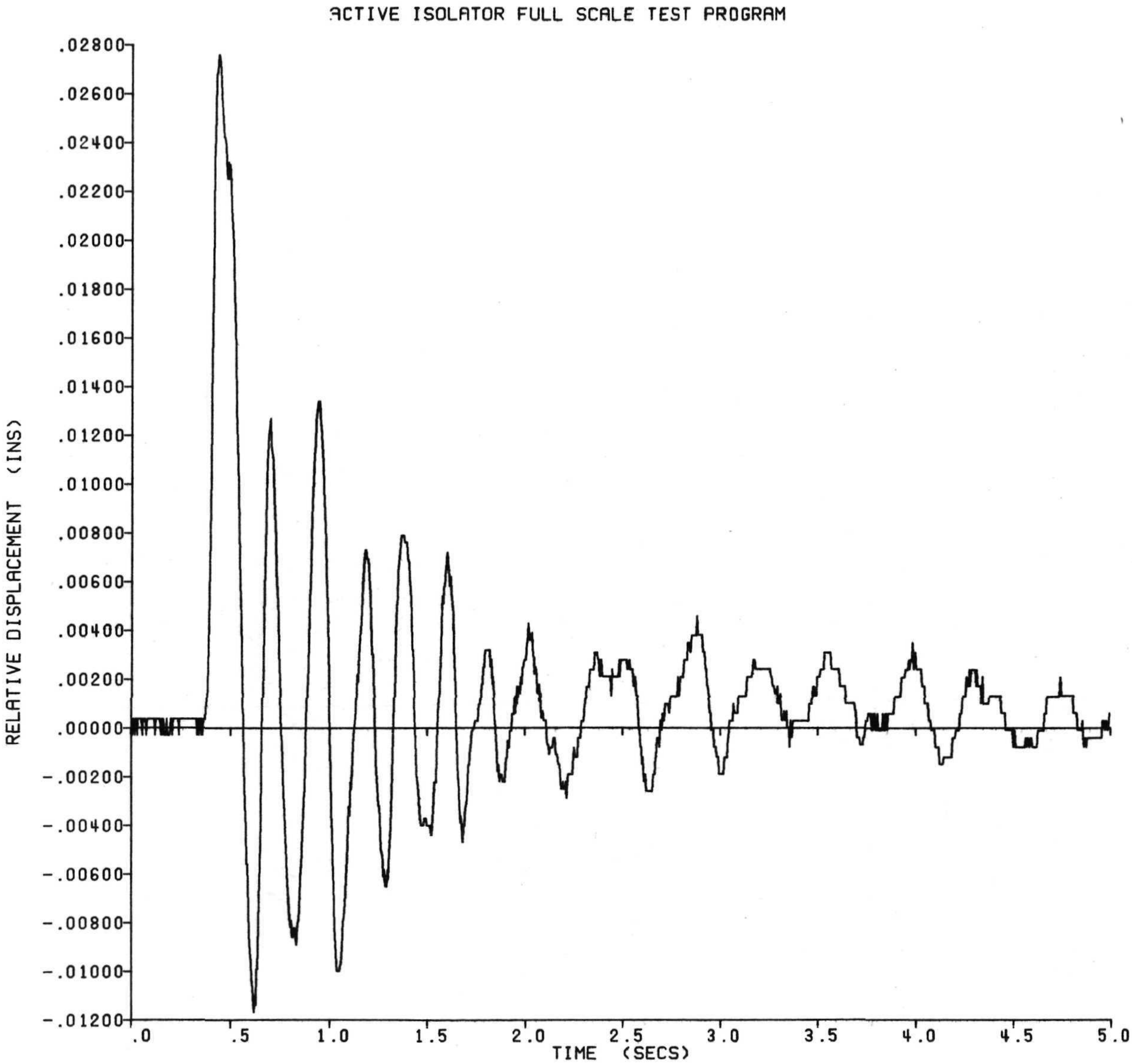

Figure 50. - Relative Deflection Between Airframe and Transmission Interface.

ACTIVE ISOLATOR FULL SCALE TEST PROGRAM

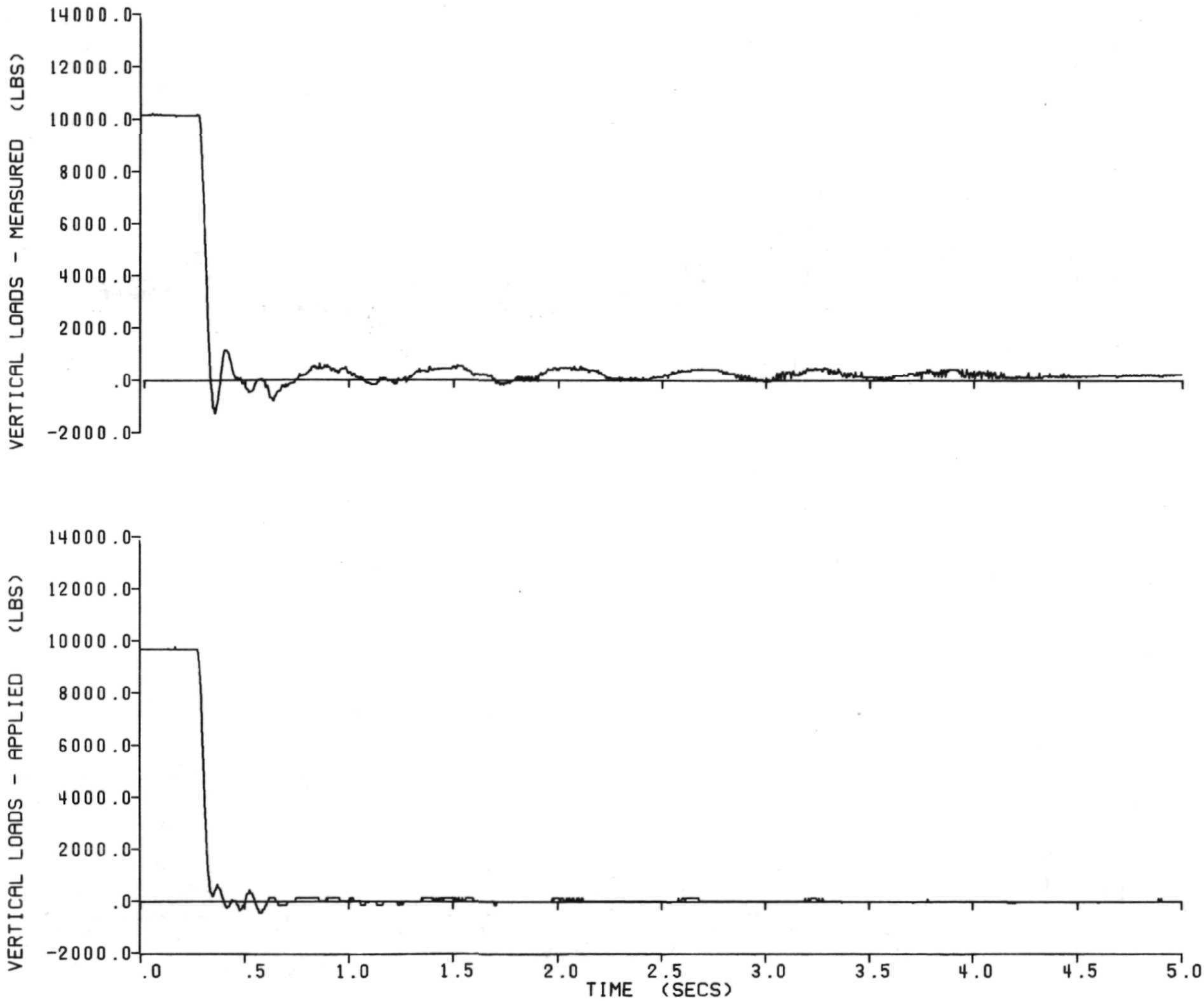

Figure 51. - Vertical Transient Response.

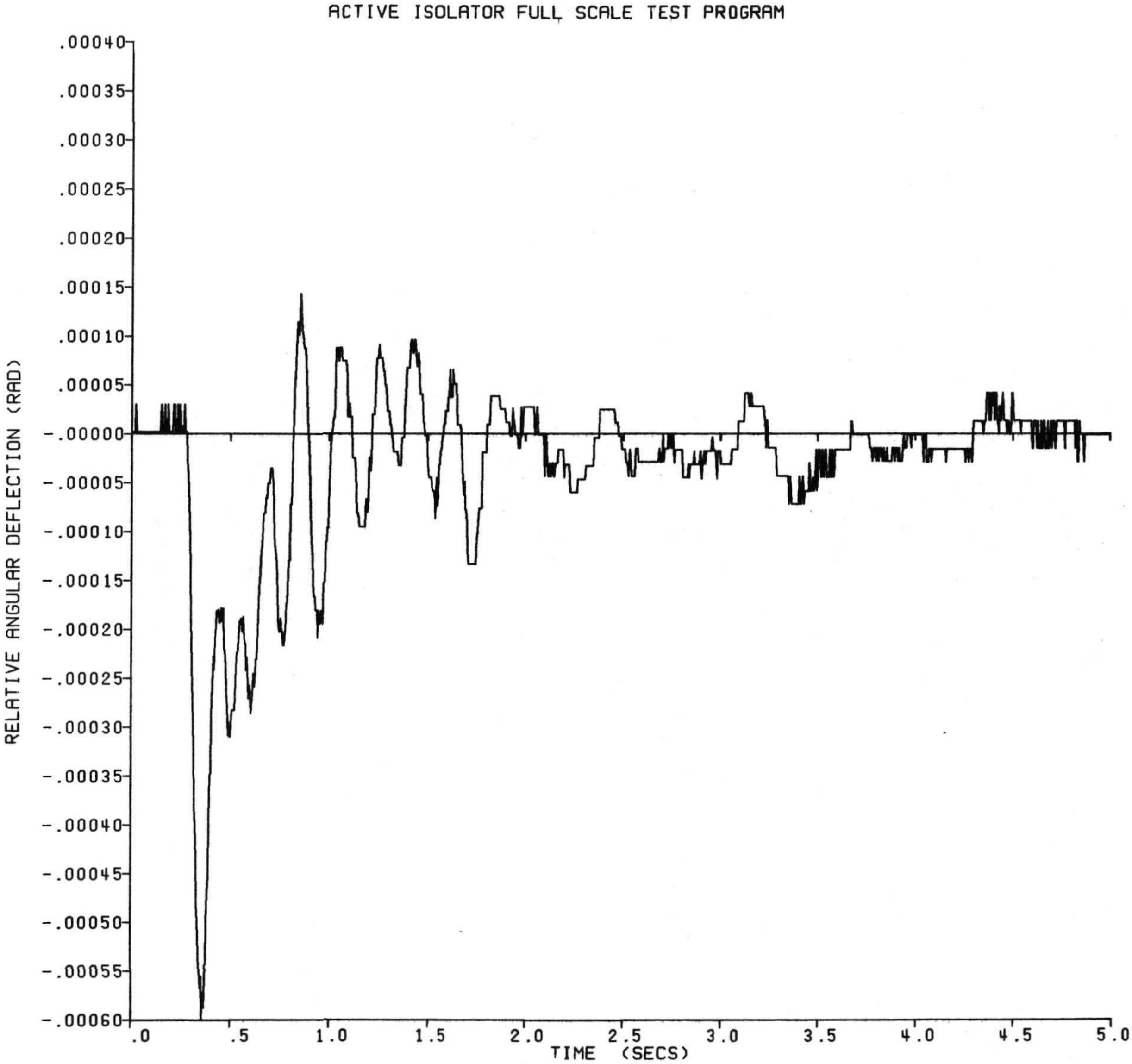

Figure 52. - Angular Deflection Between Airframe and Transmission Interface.

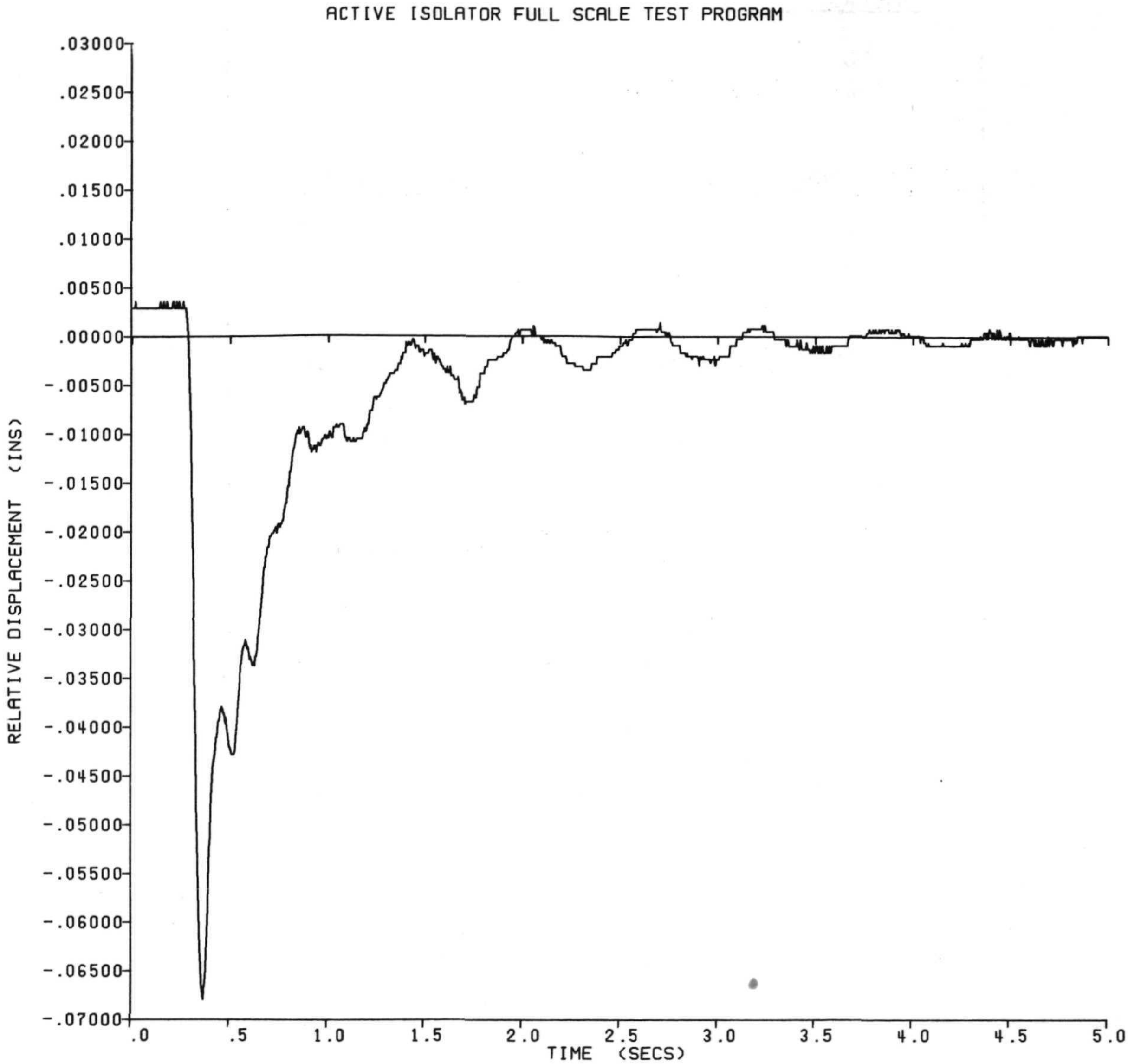

Figure 53. - Relative Deflection Between Airframe and Transmission Interface.

TABLE 1. BENCH TEST ISOLATOR PARAMETERS

<u>ISOLATOR GAIN</u>

50	
100	(NOMINAL)
200	

<u>ISOLATOR LOW SIDE PRECHARGE PRESSURE (PSI)</u>

150	
300	(NOMINAL)
500	

<u>ISOLATOR HIGH SIDE PRECHARGE PRESSURE (PSI)</u>

550	
1100	(NOMINAL)
1820	

<u>FLUID DAMPING ORIFICE DIAMETER (INCHES)</u>

.201	
.221	(NOMINAL)

TABLE II. - TEST SUMMARY STEADY APPLIED VERSUS MEASURED LOADS

Steady lift		Steady Longitudinal		Steady torque	
Applied	Measured	Applied	Measured	Applied	Measured
lbs	lbs	lbs	lbs	ft-lbs	ft-lbs
34200	35070	—	—	—	—
24500	25500	—	—	—	—
29200	29750	—	—	—	—
31250	31750	—	—	—	—
34000	34000	—	—	—	—
34200	34620	4130	4170	—	—
	34800	4180	4220	—	—
	34620	1013	1147	—	—
	33880	1987	2037	—	—
	32990	2894	2994	—	—
	34110	4129	4220	—	—
	34370	—	—	78800	81000
	34580	—	—	80600	83000
	34510	—	—	25500	25900
	33810	—	—	49000	48700
	34310	—	—	79200	79100
34200	34360	5435	3260	78300	80100

TABLE III - TEST SUMMARY OF VIBRATORY APPLIED VERSUS MEASURED LOADS

Steady lift		Steady Longitudinal		Steady torque		Vibratory frequency	Vibratory loads					
Applied	Measured	Applied	Measured	Applied	Measured		Vertical		Lateral		Longitudinal	
							Applied	Measured	Applied	Measured	Applied	Measured
lbs	lbs	lbs	lbs	ft-lbs	ft-lbs	Hz	−lbs/phase	±lbs/phase	±lbs/phase	±lbs/phase	±lbs/phase	±lbs/phase
34200	33700	—	—	—	—	10	720/0°	2150/−24°	0/0°	140/54°	0/0°	410/−101°
↓	35120	—	—	—	—	18.5	1000/0°	935/0°	0/0°	60/0°	0/0°	270/0°
	33780	—	—	—	—	30	500/0°	730/0°	0/0°	10/0°	0/0°	20/0°
	34290	—	—	—	—	10	0/0°	280/0°	0/0°	100/0°	720/0°	1120/0°
	34280	—	—	—	—	18.5	0/0°	75/0°	0/0°	80/0°	1000/0°	1270/0°
	34240	—	—	—	—	30	0/0°	40/0°	0/0°	0/0°	500/0°	530/0°
	35080	—	—	—	—	10	0/0°	860/−154°	750/0°	1900/0.3°	0/0°	420/−138°
	34980	—	—	—	—	18.5	0/0°	10/0°	1000/0°	1350/0°	0/0°	40/0°
	34930	—	—	—	—	30	0/0°	0/0°	500/0°	580/0°	0/0°	50/0°
	35900	—	—	—	—	10	510/0°	970/−31°	0/0°	120/19°	510/0°	1300/−55°
	37200	—	—	—	—	18.5	990/0°	1110/0°	0/0°	140/0°	990/0°	1310/0°
	36100	—	—	—	—	30	495/0°	350/0°	0/0°	50/0°	495/0°	510/0°
	34900	—	—	—	—	10	510/0°	910/108°	510/0°	890/1.4°	0/0°	580/98°
	34900	—	—	—	—	18.5	990/0°	560/0°	990/0°	1460/0°	0/0°	190/0°
	34980	—	—	—	—	30	495/0°	200/0°	495/0°	530/0°	0/0°	30/0°
	34100	882	1609	38000	39300	10	360/0°	1420/123°	360/0°	910/42°	0/0°	220/131°
↓	34120	945	1650	40200	41100	18.5	990/0°	1020/0°	990/0°	1310/0°	0/0°	650/0°
34200	34000	856	1684	40200	41400	30	350/0°	360/0°	350/0°	340/0°	0/0°	60/0°

APPENDIX I

Active Isolator Precharge Calculations

In establishing the system precharge pressures, it was determined that the individual isolator spring rates would be set to the 10,000 pound per inch value utilized during the test of Reference 2.

The equations for both the high and low pressure side spring rates as a function of system operating conditions are developed in Reference 2. It is seen that the spring rate at high frequencies is proportional to the operating pressure, piston cross-sectional area, and inversely proportional to the operating volume between the diaphram and flow restrictor. This equation is given as:

$$K_{a,b} = \frac{P_{a,b}\, A^2_{a,b}}{V_{ca',b'}}$$

The piston area has not changed, and thus spring rate is proportional to the ratio of $P_{a,b}$ to $V_{ca',b'}$ solely. A sample calculation of the required precharge pressures for isolator #1 is presented. Calculations for the remaining units are identical in nature. From the data for the original configuration (Table I-1), it is seen that the high pressure side spring rate is proportional to the following ratio:

$$K \propto \frac{P_b}{V_{cb'}} = \frac{1100}{16} = 68.8$$

The high side operating pressure for isolator #1 is measured at 1300 psi. Therefore, the new high pressure side operating volume Vcb' required to maintain the same spring rate is:

$$V_{cb'} = \frac{1300}{68.8} = 18.9$$

The total available air volume is given as:

$$V_{tb} + V_{cb_o} = 14.2 + 26.6 = 40.8$$

The total high pressure side air volume under operating conditions for isolator #1 is:

$$V_{tb} + V_{cb'} = 14.2 + 18.9 = 33.1$$

The air pressure under operating conditions is equal to the hydraulic fluid operating pressure P_b. Therefore, assuming adiabatic expansion, the required precharge pressures can be determined from the following relationship:

$$P_H \; (V_{tb} + V_{cb_o}) = P_b \; (V_{tb} + V_{cb'})$$

Therefore,

$$P_H = \frac{(1300)(33.1)}{(40.8)} = 1050 \text{ psi}$$

In a similar manner for the low pressure side of isolator #1:

$$Vca' = \frac{(420)(6)}{300} = 8.4$$

$$Vta + Vca_o = 7.1 + 26.6 = 33.7$$

$$Vta + Vca' = 7.1 + 8.4 = 15.5$$

Therefore,

$$P_L = \frac{(420)(15.5)}{(33.7)} = 193 \text{ psi}$$

A summary of all measured and calculated parameters for the three units and the basic configuration is presented in Table I-1.

TABLE I-1 ACTIVE ISOLATOR MEASURED AND CALCULATED OPERATING PARAMETERS

	Original Configuration	Isolator 1	Isolator 2	Isolator 3
Vca_o	26.6	26.6	26.6	26.6
Vcb_o	26.6	26.6	26.6	26.6
Vta	7.1	7.1	7.1	7.1
Vtb	14.2	14.2	14.2	14.2
Pa	300	420	400	250
Pb	1100	1300	1150	900
Vca'	6	8.4	8	5
Vcb'	16	18.9	16.7	13.1
P_H	810	1050	870	600
P_L	116	193	179	90

APPENDIX II

APPLICATIONS OF ACTIVE ISOLATION TO SLOWED ROTORS

Considering a reduction of 50 percent in main rotor operating speed, the resulting N/Rev frequency would be reduced by a factor of 2 to 555 CPM. At this frequency, the degree of vertical isolation is not considered acceptable (Figures 32 to 35). Shifting of isolator modes to maintain the desired N/Rev isolation can be obtained by lowering the existing spring rate in each isolator. By lowering the spring rate and maintaining a constant ratio of N/Rev frequency to isolator mode frequencies, the amount of isolation at 555 CPM must be comparable to that obtained with the configuration tested at a forcing frequency of 1110 CPM. The location of inplane and vertical isolator modes, with the lower spring rate and reduced rotor speed are compared with the original spectrum obtained at normal operating conditions in Figure (II-1). No amplification at 1/Rev would result since this frequency is also reduced by 50 percent.

In order to achieve the modes at the indicated frequencies (Figure II-1), the isolator spring rates would have to be reduced from the 10,000 pounds per inch tested, to 2500 pounds per inch. Assuming system operating pressures to remain constant the required air volumes and precharge pressures required to produce this spring rate are calculated as follows:

From the data of Appendix I - $K \propto \frac{68.8}{4} = 17.2$

resulting in a new high pressure side operating volume:

$$Vcb' = \frac{1300}{17.2} = 75.6$$

The total available air volume remains at 40.8 in^3, however, the new required air volume under operating conditions is:

$$Vtb + Vcb' = 14.2 + 75.6 = 89.8$$

Since the required air volume exceeds the existing volume, by 49 in^3, an additional supply is required.

Assuming additional air volume capabilities, including those existing, totaled 100 in^3, the high air precharge pressure could be calculated from the relationship derived in Appendix I or:

$$P_H = \frac{(1300)\ (89.8)}{100} = 1168 \text{ psi}$$

In a similar manner for the low pressure side:

$$K \propto \frac{50}{4} = 12.5 \qquad \text{and}$$

$$Vca' = \frac{420}{12.5} = 33.6$$

$$Vta + Vca' = 7.1 + 33.6 = 40.7$$

Since the total existing available air volume is 33.7, the capability for expansion is considered. Therefore, an air volume capability totaling 50 in^3 is used. The low air precharge pressure is found to be:

$$P_L = \frac{(420)\ (40.7)}{50} = 336 \text{ psi}$$

This analysis indicates that available air volumes in the prototype units is inadequate by approximately 50 cubic inches for the high pressure side and 20 cubic inches on the low pressure side.

In order to expand the existing wide band isolation capabilities, air volumes which can be utilized as required would be needed in a universal system. A conceptual schematic of such a system is presented in Figure II-2. The load measurement capability has been determined to be independant of isolator stiffness.

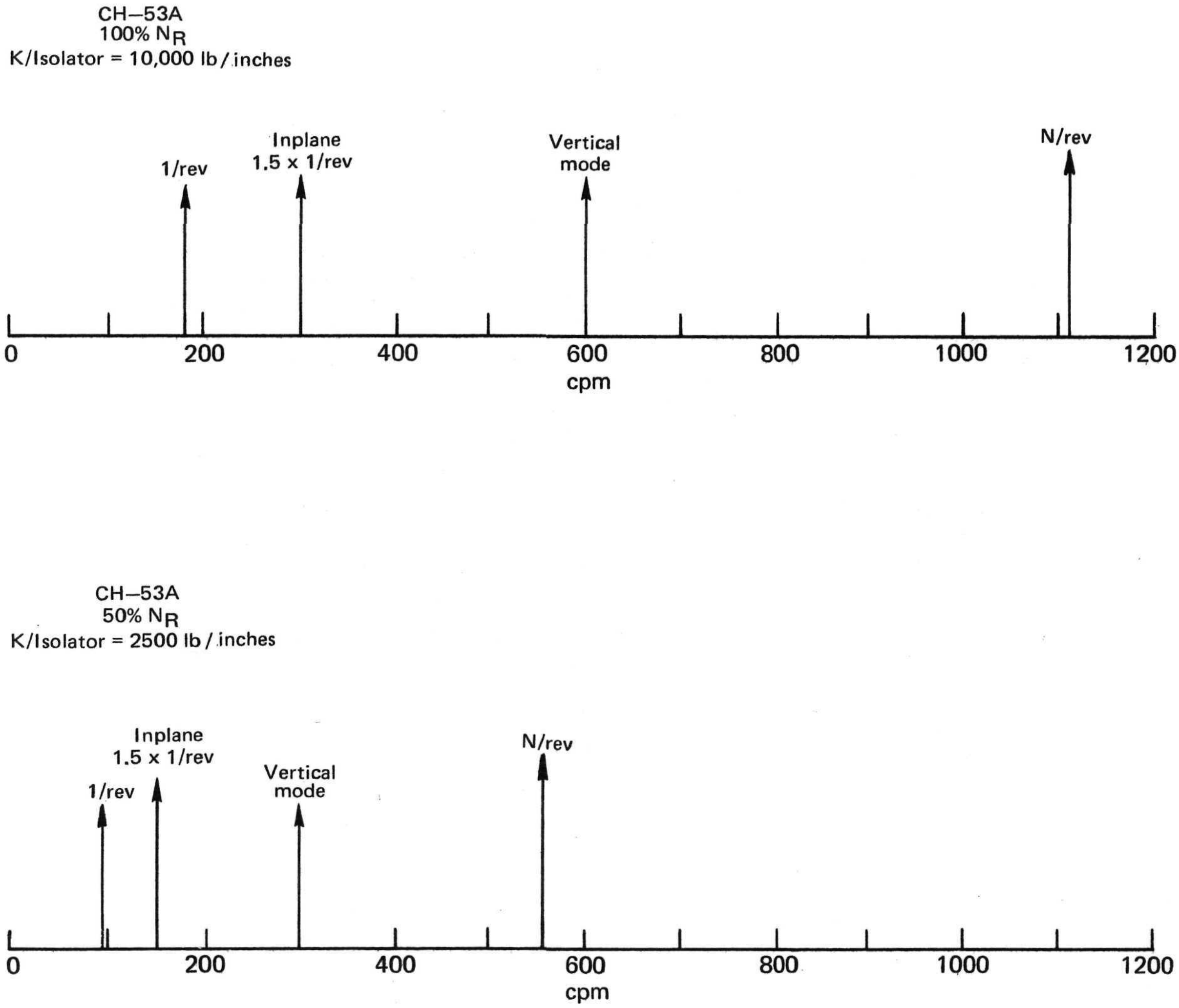

Figure II-1 - Effect of Rotor RPM on Required Isolator Spring Rates.

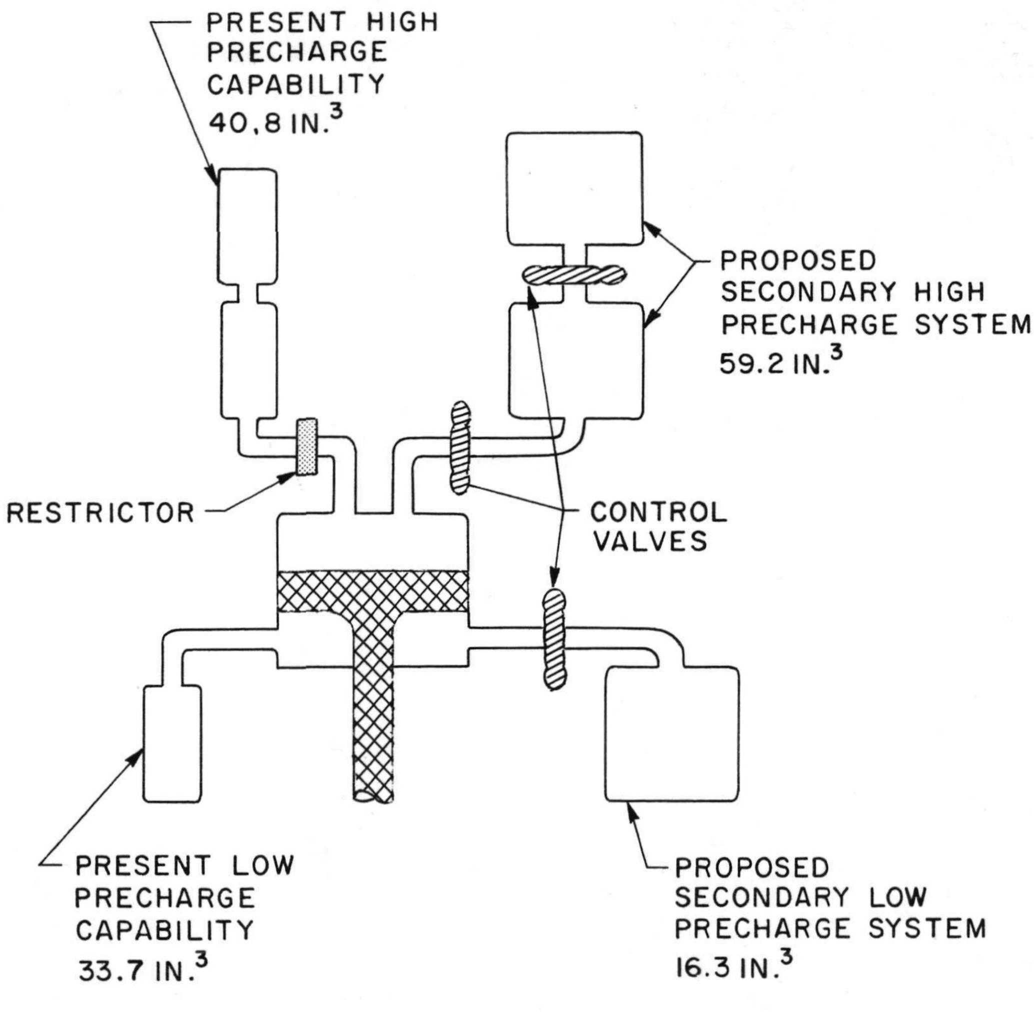

Figure II-2 - Proposed Universal Isolation System.

APPENDIX III

Computer Program Definition

APPENDIX III-A

Sikorsky Aircraft has developed computer programs to analyze data produced by isolation and rotor loads testing. This data may be of two kinds:

(1) That produced in a steady or vibratory test. The data produced from actual test cases is keypunched and input to program Y164A along with geometry and mass property information. From this data, the applied and measured forces acting on the system are calculated. Samples of actual test cases and a complete program listing are presented. A listing of this program is presented in Appendix III-B.

(2) The data resulting from transient testing. The actual data is recorded on analog tape, digitized, and used as a series of time points as input to program Y164E, to calculate the forces in time history form.

The various program in the analysis package are described as follows:

Y164A (1108)

For steady or vibratory conditions: Takes recorded keypunched data, plus geometry and mass data in LOADER format, and isolator calibration curves in CLOAD format, and performs calculations to obtain the forces acting on the system.

This program handles the steady and vibratory case on its own. For the transient case, a sequence of programs must be run in addition to Y164A. The sequence is as follows:

Y164B (360)

Initializes disk area and stores basic problem description and dimensions.

Y164C (360)

Takes digital tape content in 9-bit words, validates, removes 'sets' inserted for reduction purposes and stores the result on disk, where one direct access record has data for all gages over 72 points.

Y164D (360)

Determines calibration of disk data, further validates and summarizes data ready for third-pass program, Y164E.

Y164E (360)

Third-pass program. This takes data from disk using subroutine GETPTS, together with LOADER and CLOAD data, and generates time histories of the forces on the system. These are written on tape.

Y164F (360)

This program takes the data recorded on tape, and uses time history plotting techniques to produce Benson-Lehner plots.

APPENDIX III-B

COMPUTER PROGRAM LISTING

THIS DECK WAS PROCESSED BY ENG. COMPUTER SERVICES ON JANUARY 30, 1973.

```
1        1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0    U1005 CD COUNT

@IP FOR IRBS,IRBS                                                                    00001
C                                                                       IRBS0010    00002
C                                                                       IRBS0020    00003
C     ISOLATOR RB SYSTEM PROGRAM .                                      IRBS0030    00004
C                                                                       IRBS0040    00005
C     ALL QUESTIONS - REFER  ART MILTON X 1658                          IRBS0050    00006
C                       OR   G.C.THOMAS X 2368                          IRBS0060    00007
C                                                                       IRBS0070    00008
C                                                                       IRBS0080    00009
C                                                                       IRBS0090    00010
C                                                                       IRBS0100    00011
C     SWITCHES ---                                                      IRBS0110    00012
C                                                                       IRBS0120    00013
C        ITYPE    =  0  STEADY                                          IRBS0130    00014
C                 =  1  VIBRATORY                                       IRBS0140    00015
C        IRIGID   =  0  NON-RIGID                                       IRBS0150    00016
C                 =  1  RIGID                                           IRBS0160    00017
C        IEND     =  0  STACK RECORDED DATA                             IRBS0170    00018
C                 =  1  STACK LOADER DATA                               IRBS0180    00019
C                 = -1  STOP                                            IRBS0190    00020
C                                                                       IRBS0200    00021
C                                                                       IRBS0210    00022
C                                                                       IRBS0220    00023
      DIMENSION NC(4),LOC(8),X(1000),Y(1000),Z(500)                     IRBS0230    00024
      DIMENSION V(200)                                                  IRBS0240    00025
      COMMON /IAIBIG/ IA,IB,IG,JSIZE,IPRINT                             IRBS0250    00026
C                                                                       IRBS0260    00027
      DIMENSION D(17),FIM(3),FIT(3),ERROR(3)                            IRBS0270    00028
      DIMENSION R(29,3),IR(29,3)                                        IRBS0280    00029
      DIMENSION  PHV(3) , PLV(3) , PHS(3) , PLS(3) , PHP(3) , PLP(3) ,  IRBS0290    00030
     1           FHV(3) , FLV(3) , XX(3)  , YY(3)  , FIV(3) , FIVP(3),  IRBS0300    00031
     2           FITS(3), FLCT(4)                                       IRBS0310    00032
      DIMENSION FIVPX(3)                                                IRBS0320    00033
C                                                                       IRBS0330    00034
      DIMENSION TITL1(12),TITL2(12),NAME1(2),NAME2(2),DATE(2)           IRBS0340    00035
      DIMENSION TITL3(12)                                               IRBS0350    00036
C                                                                       IRBS0360    00037
      REAL IOXUB1,IOYUB1,IOXUB2,IOYUB2,IOXLB ,IOYLB ,IOXUB ,IOYUB ,     IRBS0370    00038
     1     IXAC  ,IYAC  ,MXA   ,MYA   ,MZA   ,MXAM  ,MYAM  ,MZAM  ,     IRBS0380    00039
     2     MXAA  ,MYAA  ,MZAA                                           IRBS0390    00040
C                                                                       IRBS0400    00041
      DIMENSION IERR(3)                                                 IRBS0410    00042
      DATA IERR/'ERROR1ERROR2ERROR3'/                                   IRBS0420    00043
C                                                                       IRBS0430    00044
      DIMENSION ITEMS(29)                                               IRBS0440    00045
      DATA ITEMS/'DR    TAP1  TAP2  FLC1T FLC2T FLC3T FLC4T P1H   P1L   IRBS0450    00046
     1P2H   P2L   P3H   P3L   DEL1  DEL2  DEL3  ACC1  ACC2  ACC3  ACC4  IRBS0460    00047
     2ACC5  ACC6  ACC7  ACC8  ACC9  ACC10 ACC11 ACC12 ACC13 '/          IRBS0470    00048
C                                                                       IRBS0480    00049
C                                                                       IRBS0490    00050
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0    U1005 CD COUNT

      EQUIVALENCE       (V(  1),TYPE  ),(V(  2),RIGID )                   IRBS0500    00051
      EQUIVALENCE       (V(  7),DEBUG )                                   IRBS0510    00052
C                                                                         IRBS0520    00053
      EQUIVALENCE       (V( 11),WUB1  ),(V( 12),XUB1  ),(V( 13),YUB1  ),  IRBS0530    00054
     1 (V( 14),ZUB1  ),(V( 15),IOXUB1),(V( 16),IOYUB1),(V( 17),WUB2  ),  IRBS0540    00055
     2 (V( 18),XUB2  ),(V( 19),YUB2  ),(V( 20),ZUB2  ),(V( 21),IOXUB2),  IRBS0550    00056
     3 (V( 22),IOYUB2),(V( 23),WLB   ),(V( 24),XLB   ),(V( 25),YLB   ),  IRBS0560    00057
     4 (V( 26),ZLB   ),(V( 27),IOXLB ),(V( 28),IOYLB ),(V( 29),XI1   ),  IRBS0570    00058
     5 (V( 30),YI1   ),(V( 31),XI2   ),(V( 32),YI2   ),(V( 33),XI3   ),  IRBS0580    00059
     6 (V( 34),YI3   ),(V( 35),XLC1  ),(V( 36),YLC1  ),(V( 37),ZLC1  ),  IRBS0590    00060
     7 (V( 38),XLC2  ),(V( 39),YLC2  ),(V( 40),ZLC2  ),(V( 41),XLC3  ),  IRBS0600    00061
     8 (V( 42),YLC3  ),(V( 43),ZLC3  ),(V( 44),XLC4  ),(V( 45),YLC4  ),  IRBS0610    00062
     9 (V( 46),ZLC4  ),(V( 47),XTAP1 ),(V( 48),YTAP1 ),(V( 49),ZTAP1 ),  IRBS0620    00063
     A (V( 50),ALPHA1),(V( 51),XTAP2 ),(V( 52),YTAP2 ),(V( 53),ZTAP2 ),  IRBS0630    00064
     B (V( 54),ALPHA2),(V( 55),XP    ),(V( 56),YP    ),(V( 57),ZP    ),  IRBS0640    00065
     C (V( 58),BETA  ),(V( 59),XA    ),(V( 60),YA    ),(V( 61),ZA    ),  IRBS0650    00066
     D (V( 62),AH    ),(V( 63),AL    ),(V( 64),PA    ),(V( 65),PB    ),  IRBS0660    00067
     E (V( 66),G     ),(V( 67),CV    )                                   IRBS0670    00068
      EQUIVALENCE       (V( 70),XA1   ),(V( 71),YA1   ),(V( 72),ZA1   ),  IRBS0680    00069
     1                  (V( 73),XA2   ),(V( 74),YA2   ),(V( 75),ZA2   ),  IRBS0690    00070
     2                  (V( 76),XA3   ),(V( 77),YA3   ),(V( 78),ZA3   ),  IRBS0700    00071
     3                  (V( 79),XA4   ),(V( 80),YA4   ),(V( 81),ZA4   ),  IRBS0710    00072
     4                  (V( 82),XA5   ),(V( 83),YA5   ),(V( 84),ZA5   ),  IRBS0720    00073
     5                  (V( 85),XA6   ),(V( 86),YA6   ),(V( 87),ZA6   ),  IRBS0730    00074
     6                  (V( 88),XA7   ),(V( 89),YA7   ),(V( 90),ZA7   ),  IRBS0740    00075
     7                  (V( 91),XA8   ),(V( 92),YA8   ),(V( 93),ZA8   ),  IRBS0750    00076
     8                  (V( 94),XA9   ),(V( 95),YA9   ),(V( 96),ZA9   ),  IRBS0760    00077
     9                  (V( 97),XA10  ),(V( 98),YA10  ),(V( 99),ZA10  ),  IRBS0770    00078
     A                  (V(100),XA11  ),(V(101),YA11  ),(V(102),ZA11  ),  IRBS0780    00079
     B                  (V(103),XA12  ),(V(104),YA12  ),(V(105),ZA12  ),  IRBS0790    00080
     C                  (V(106),XA13  ),(V(107),YA13  ),(V(108),ZA13  ),  IRBS0800    00081
     D                  (V(109),SF    ),(V(110),SFREQ ),(V(111),XSH   ),  IRBS0810    00082
     E                  (V(112),YSH   ),(V(113),ZSH   ),(V(114),THTLAT),  IRBS0820    00083
     F                  (V(115),THTLON)                                   IRBS0830    00084
      EQUIVALENCE        (V(116),VERVM ),(V(117),AINPVM)                              00085
C                                                                         IRBS0840    00086
C                                                                         IRBS0850    00087
      COMMON /RDUSED/   DR    ,TAP1  ,TAP2  ,FLC1T ,FLC2T ,               IRBS0860    00088
     1                  FLC3T ,FLC4T ,P1H   ,P1L   ,P2H   ,               IRBS0870    00089
     2                  P2L   ,P3H   ,P3L   ,DEL1  ,DEL2  ,               IRBS0880    00090
     3                  DEL3  ,ACC1  ,ACC2  ,ACC3  ,ACC4  ,               IRBS0890    00091
     4                  ACC5  ,ACC6  ,ACC7  ,ACC8  ,ACC9  ,               IRBS0900    00092
     5                  ACC10 ,ACC11 ,ACC12 ,ACC13                        IRBS0910    00093
      DIMENSION RD(29)                                                    IRBS0920    00094
      EQUIVALENCE (RD(1),DR)                                              IRBS0930    00095
      COMMON /RDRDRD/   DRS   ,TAP1S ,TAP2S ,FLC1TS,FLC2TS,               IRBS0940    00096
     1                  FLC3TS,FLC4TS,P1HS  ,P1LS  ,P2HS  ,               IRBS0950    00097
     2                  P2LS  ,P3HS  ,P3LS  ,DEL1S ,DEL2S ,               IRBS0960    00098
     3                  DEL3S ,ACC1S ,ACC2S ,ACC3S ,ACC4S ,               IRBS0970    00099
     4                  ACC5S ,ACC6S ,ACC7S ,ACC8S ,ACC9S ,               IRBS0980    00100
```

```
1       1         2         3         4         5         6         7         8
.....  ..0.........0.........0.........0.........0.........0.........0.........0   U1005 CD COUNT

     5                 ACC10S,ACC11S,ACC12S,ACC13S,                          IRBS0990
     6                 DRV    ,TAP1V ,TAP2V ,FLC1TV,FLC2TV,                  IRBS1000
     7                 FLC3TV,FLC4TV,P1HV   ,P1LV   ,P2HV   ,                IRBS1010
     8                 P2LV   ,P3HV   ,P3LV   ,DEL1V ,DEL2V ,                IRBS1020
     9                 DEL3V ,ACC1V ,ACC2V ,ACC3V ,ACC4V ,                   IRBS1030
     A                 ACC5V ,ACC6V ,ACC7V ,ACC8V ,ACC9V ,                   IRBS1040
     B                 ACC10V,ACC11V,ACC12V,ACC13V,                          IRBS1050
     C                 DRP    ,TAP1P ,TAP2P ,FLC1TP,FLC2TP,                  IRBS1060
     D                 FLC3TP,FLC4TP,P1HP   ,P1LP   ,P2HP   ,                IRBS1070
     E                 P2LP   ,P3HP   ,P3LP   ,DEL1P ,DEL2P ,                IRBS1080
     F                 DEL3P ,ACC1P ,ACC2P ,ACC3P ,ACC4P ,                   IRBS1090
     G                 ACC5P ,ACC6P ,ACC7P ,ACC8P ,ACC9P ,                   IRBS1100
     H                 ACC10P,ACC11P,ACC12P,ACC13P                           IRBS1110
      EQUIVALENCE (DRS,R(1,1))                                               IRBS1120
C                                                                            IRBS1130
C                                                                            IRBS1140
      EXTERNAL SELLIN                                                        IRBS1150
C                                                                            IRBS1160
C     READ TITLES,USERS,DATE                                                 IRBS1170
C                                                                            IRBS1180
      READ (5,10)TITL1,NAME1,NAME2,DATE                                      IRBS1200
   10 FORMAT(12A6/6A6)                                                       IRBS1210
C                                                                            IRBS1220
C     READ AND PLOT ERROR CURVE DATA                                         IRBS1230
C                                                                            IRBS1240
      JSIZE =1000                                                            IRBS1250
      CALL CLOAD(NC,LOC,X,Y,Z)                                               IRBS1260
      DO 20 I=1,3                                                            IRBS1270
      CALL CPLOT(NC(I),NC,LOC,X,Y,Z)                                         IRBS1280
   20 CONTINUE                                                               IRBS1290
C                                                                            IRBS1300
C     READ LOADER DATA                                                       IRBS1310
C                                                                            IRBS1320
      DO 30 I=1,200                                                          IRBS1330
   30 V(I)=0.                                                                IRBS1340
   40 CONTINUE                                                               IRBS1350
      READ (5,50)TITL2                                                       IRBS1360
   50 FORMAT(12A6)                                                           IRBS1370
      ALPHA1 = ALPHA1 * 57.29578                                             IRBS1380
      ALPHA2 = ALPHA2 * 57.29578                                             IRBS1390
      BETA   = BETA   * 57.29578                                             IRBS1400
      CALL LOADER(V)                                                         IRBS1410
      IDEBUG = DEBUG                                                         IRBS1190
      IVERVM = VERVM
      INPVM  = AINPVM
C                                                                            IRBS1420
C                                                                            IRBS1430
C   CALCULATE MASS DATA                                                      IRBS1440
C                                                                            IRBS1450
      WUB    = WUB1+WUB2                                                     IRBS1460
```

```
1        1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0        U1005 CD COUNT
      XUB   = (WUB1*XUB1+WUB2*XUB2)/WUB                                           IRBS1470     00151
      YUB   = (WUB1*YUB1+WUB2*YUB2)/WUB                                           IRBS1480     00152
      ZUB   = (WUB1*ZUB1+WUB2*ZUB2)/WUB                                           IRBS1490     00153
      IOXUB = IOXUB1+IOXUB2 + WUB1*((YUB1-YUB)**2 +(ZUB1-ZUB)**2)/386.            IRBS1500     00154
     1                      + WUB2*((YUB2-YUB)**2 +(ZUB2-ZUB)**2)/386.            IRBS1510     00155
      IOYUB = IOYUB1+IOYUB2 + WUB1*((XUB1-XUB)**2 +(ZUB1-ZUB)**2)/386.            IRBS1520     00156
     1                      + WUB2*((XUB2-XUB)**2 +(ZUB2-ZUB)**2)/386.            IRBS1530     00157
C                                                                                 IRBS1540     00158
      WAC   = WUB+WLB                                                             IRBS1550     00159
      XAC   = (WUB*XUB+WLB*XLB)/WAC                                               IRBS1560     00160
      YAC   = (WUB*YUB+WLB*YLB)/WAC                                               IRBS1570     00161
      ZAC   = (WUB*ZUB+WLB*ZLB)/WAC                                               IRBS1580     00162
      IXAC  = IOXUB + IOXLB + WUB *((YUB-YAC)**2 + (ZUB-ZAC)**2)/386.             IRBS1590     00163
     1                      + WLB *((XLB-XAC)**2 + (ZLB-ZAC)**2)/386.             IRBS1600     00164
      IYAC  = IOYUB + IOYLB + WUB *((XUB-XAC)**2 + (ZUB-ZAC)**2)/386.             IRBS1610     00165
     1                      + WLB *((XLB-XAC)**2 + (ZLB-ZAC)**2)/386.             IRBS1620     00166
C                                                                                 IRBS1630     00167
C   PRINT TITLE INFORMATION                                                       IRBS1640     00168
C                                                                                 IRBS1650     00169
      WRITE (6,60)TITL1,NAME1,NAME2,DATE,TITL2                                    IRBS1660     00170
   60 FORMAT(1H1,29X,12A6/30X,72('-')///                                          IRBS1670     00171
     1 40X,'PREPARED BY    ',2A6 //                                               IRBS1680     00172
     2 40X,'CHECKED  BY    ',2A6 //                                               IRBS1690     00173
     3 40X,'DATE           ',2A6 ///                                              IRBS1700     00174
     4 30X, 12A6/30X,72('-') /)                                                   IRBS1710     00175
C                                                                                 IRBS1720     00176
C     PRINT INPUT, MASS AND GEOMETRY                                              IRBS1730     00177
C                                                                                 IRBS1740     00178
      WRITE (6,520)                                                               IRBS1750     00179
      WRITE (6,530)WUB1,WUB2,WUB,WLB,WAC,XUB1,XUB2,XUB,XLB,XAC,YUB1,YUB2IRBS1760     00180
     1,YUB,YLB,YAC,ZUB1,ZUB2,ZUB,ZLB,ZAC,IOXUB1,IOXUB2,IOXUB,IOXLB,IXAC,IRBS1770     00181
     2IOYUB1,IOYUB2,IOYUB,IOYLB,IYAC                                              IRBS1780     00182
      WRITE (6,540)                                                               IRBS1790     00183
      WRITE (6,550)(V(I),I=29,34)                                                 IRBS1800     00184
      WRITE (6,560)                                                               IRBS1810     00185
      WRITE (6,570)(V(I),I=35,46)                                                 IRBS1820     00186
      WRITE (6,580)                                                               IRBS1830     00187
      WRITE (6,590)(V(I),I=47,54)                                                 IRBS1840     00188
      WRITE (6,600)                                                               IRBS1850     00189
      DO 70 J=1,13                                                                IRBS1860     00190
      J1 =   3*(J-1)+70                                                           IRBS1870     00191
      J2 =   3*J    +69                                                           IRBS1880     00192
      WRITE (6,620)J,(V(I),I=J1,J2)                                               IRBS1890     00193
   70 CONTINUE                                                                    IRBS1900     00194
      WRITE (6,610)                                                               IRBS1910     00195
      WRITE (6,630)(V(I),I=55,58)                                                 IRBS1920     00196
      WRITE (6,640)XSH,YSH,ZSH                                                    IRBS1930     00197
      WRITE (6,650)(V(I),I=59,61)                                                 IRBS1940     00198
      WRITE (6,660)PA,AH,PB,AL,G,CV                                               IRBS1950     00199
      WRITE (6,670)SF,THTLON,SFREQ,THTLAT                                         IRBS1960     00200
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0

C  CONVERT ANGLES TO RADIANS                                            IRBS1970
      ALPHA1 = ALPHA1/57.29578                                          IRBS1980
      ALPHA2 = ALPHA2/57.29578                                          IRBS1990
      BETA   = BETA  /57.29578                                          IRBS2000
C                                                                       IRBS2010
C  CALCULATE GEOMETRY                                                   IRBS2020
C                                                                       IRBS2030
      D( 1) = YI2  -YA                                                  IRBS2040
      D( 2) = YA   -YI3                                                 IRBS2050
      D( 3) = ZA   -ZLC1                                                IRBS2060
      D( 4) = YUB  -YA                                                  IRBS2070
      D( 5) = XA   -XI1                                                 IRBS2080
      D( 6) = XI2  -XA                                                  IRBS2090
      D( 7) = XA   -XUB                                                 IRBS2100
      D( 8) = YA   -YLC1                                                IRBS2110
      D( 9) = XA   -XLC2                                                IRBS2120
      D(10) = YLC3 -YA                                                  IRBS2130
      D(11) = XLC4 -XA                                                  IRBS2140
      D(12) = XA   -XTAP1                                               IRBS2150
      D(13) = YTAP1-YA                                                  IRBS2160
      D(14) = XTAP2-XA                                                  IRBS2170
      D(15) = YA   -YTAP2                                               IRBS2180
      D(16) = XP   -XA                                                  IRBS2190
      D(17) = ZP   -ZA                                                  IRBS2200
C PRINT CALCULATED GEOMETRY TEMPORARILY                                 IRBS2210
      WRITE (6,80)D                                                     IRBS2220
   80 FORMAT(///' *** D ***'//(5F15.3/))                                IRBS2230
C                                                                       IRBS2240
C   READ CARD INPUT OF RECORDED DATA, 29 CARDS ,NUMBERED 1 - 29 ,       IRBS2250
C                                                                       IRBS2260
C                                      3 NUMBERS PER CARD               IRBS2270
C                                                                       IRBS2280
   90 CONTINUE                                                          IRBS2290
      READ (5,100)TITL3,IEND                                            IRBS2300
  100 FORMAT(12A6,6X,I2)                                                IRBS2310
      DO 170 I=1,29                                                     IRBS2320
      READ (5,110)J,(IR(I,K),K=1,3)                                     IRBS2330
      IF (J.NE.I) WRITE (6,120)J,I                                      IRBS2340
  110 FORMAT(I5,3I10)                                                   IRBS2350
  120 FORMAT(' *** ERROR IN INDEX OF RECORDED DATA .'/                  IRBS2360
     1       '      INDEX READ       ', I5/                             IRBS2370
     2       '      INDEX SHOULD BE ', I5)                              IRBS2380
C                                                                       IRBS2390
C  PERFORM VARIOUS DATA CHANGES                                         IRBS2400
C                                                                       IRBS2410
      DO 130 K=1,3                                                      IRBS2420
  130 R(I,K)=IR(I,K)                                                    IRBS2430
C DIVIDE DEFLECTION DATA BY 1000.                                       IRBS2440
      IF (I.LT.14.OR.I.GT.16) GO TO 150                                 IRBS2450
      DO 140 K=1,3                                                      IRBS2460
```

```
1       1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0

  140 R(I,K) = R(I,K)/1000.
  150 CONTINUE
C  PHASE . DIVIDE BY 100.
      R(I,3) =-R(I,3)/100. +360.
C  DIVIDE 17-29 BY 100.
      IF (I.LT.17) GO TO 160
      R(I,1) = R(I,1)/ 100.
      R(I,2) = R(I,2)/ 100.
  160 CONTINUE
C
  170 CONTINUE
C
C   PRINT RECORDED DATA
C
      WRITE (6,220)TITL3
      WRITE (6,180)(ITEMS(J),J,(R(J,I),I=1,3),J=1,29)
  180 FORMAT(///50X,'RECORDED DATA'/50X,13('-')//
     110X,'ITEM',13X,'CHANNEL',11X,'STEADY',13X,'VIBRATORY',12X,'PHASE'/
     2 //(10X,A6,13X,I2,9X,3(4X,F12.3,4X)))
C
C  S T E A D Y . PICK OFF CORRECT RECORDED DATA .
C
      DO 190 I=1,29
  190 RD(I)= R(I,1)
C  CONVERT PHASE ANGLES TO RADIANS
      DO 200 I=1,29
  200 R(I,3)=R(I,3)/ 57.29578
C
C   CALCULATE TRUE ISOLATOR LOADS
C
      FIM(1) = P1H*AH - P1L*AL
      FIM(2) = P2H*AH - P2L*AL
      FIM(3) = P3H*AH - P3L*AL
C
      DO 210 I=1,3
      CALL CIP(IERR(I),NC,LOC,X,Y,SELLIN,FIM(I),ERROR(I),DM1,DM2,DM3,2)
      FIT(I) = FIM(I) + ERROR(I)
  210 CONTINUE
C
C  CALCULATE APPLIED LOADS AT A
C
C
      SBETA=SIN(BETA)
      CBETA=COS(BETA)
      VA   = WUB+WLB-DR*SBETA
      DA   = DR*CBETA
      MYA  = DR*CBETA*D(17) + DR*SBETA*D(16)
      SA   = 0.
      MXA  = 0.
      MZA  = 0.
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0   U1005 CD COUNT

C                                                                       IRBS2970
C                                                                       IRBS2980
      WRITE (6,220)TITL3                                                IRBS2990
  220 FORMAT(1H1,29X,12A6/30X,72('-') )                                 IRBS3000
C                                                                       IRBS3010
C  PRINT EXTERNAL LOADS AND TRUE ISOLATOR LOADS                         IRBS3020
      WRITE (6,680)VA,SA,DA,MXA,MYA,MZA,(FIT(I),I=1,3)                  IRBS3030
C                                                                       IRBS3040
C  CALCULATE MEASURING SYSTEM LOADS AT A ,                              IRBS3050
C            APPLIED SYSTEM LOADS AT A   ,                              IRBS3060
C            CALCULATED LOADS AT A                                      IRBS3070
C                                                                       IRBS3080
      ALPHA = ALPHA1                                                    IRBS3090
      SALPHA=SIN(ALPHA)                                                 IRBS3100
      CALPHA=COS(ALPHA)                                                 IRBS3110
C                                                                       IRBS3120
      VAM    = FIT(1)+FIT(2)+FIT(3)                                     IRBS3130
      VAA    = VA-WUB                                                   IRBS3140
      SAM    = FLC4T - FLC2T                                            IRBS3150
      SAA    = (TAP1-TAP2)*CALPHA  +SA                                  IRBS3160
      DAM    = FLC1T - FLC3T                                            IRBS3170
      DAA    = DA + (TAP1-TAP2)*SALPHA                                  IRBS3180
      MXAM   = FIT(2)*D(1) - FIT(3)*D(2) +(FLC4T-FLC2T)*D(3)            IRBS3190
      MXAA   = MXA + D(3)*CALPHA*(TAP1-TAP2)   - WUB*D(4)               IRBS3200
      MYAM   = FIT(1)*D(5) -(FIT(2)+FIT(3))*D(6)+(FLC3T-FLC1T)*D(3)     IRBS3210
      MYAA   = MYA - WUB*D(7) +D(3)*SALPHA*(TAP2-TAP1)                  IRBS3220
      MZAM   = FLC1T*D(8) +FLC2T*D(9)+FLC3T*D(10)+FLC4T*D(11)           IRBS3230
      MZAA   = MZA - TAP1*CALPHA*D(12)-TAP1*SALPHA*D(13)                IRBS3240
     1             - TAP2*CALPHA*D(14)-TAP2*SALPHA*D(15)                IRBS3250
C                                                                       IRBS3260
      TAP12 = TAP1-TAP2                                                 IRBS3270
      VAC    = VAM+WUB                                                  IRBS3280
      SAC    = SAM- TAP12*CALPHA                                        IRBS3290
      DAC    = DAM- TAP12*SALPHA                                        IRBS3300
      MXAC   = MXAM- TAP12*CALPHA*D(3)+WUB*D(4)                         IRBS3310
      MYAC   = MYAM+ TAP12*SALPHA*D(3)+WUB*D(7)                         IRBS3320
      MZAC   = MZAM+ TAP1 *CALPHA*D(12)+ TAP1*SALPHA*D(13)              IRBS3330
     1            + TAP2 *CALPHA*D(14)+ TAP2*SALPHA*D(15)               IRBS3340
C                                                                       IRBS3350
C   PRINT OUT RESULTS                                                   IRBS3360
C                                                                       IRBS3370
      ITYPE=TYPE                                                        IRBS3380
      IF (ITYPE.NE.0) GO TO 230                                         IRBS3390
      WRITE (6,690)VAM,SAM,DAM,MXAM,MYAM,MZAM,VAA,SAA,DAA,MXAA,MYAA,MZAAIRBS3400
     1,VAC,SAC,DAC,MXAC,MYAC,MZAC                                       IRBS3410
      IF (IEND.EQ.0) GO TO 90                                           IRBS3420
      IF (IEND.EQ.1) GO TO 40                                           IRBS3430
      IF(IEND.EQ.-1)STOP                                                IRBS3440
  230 CONTINUE                                                          IRBS3450
      IRIGID = RIGID                                                    IRBS3460
```

```
1        1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0   U1005 CD COUNT

      IF (IRIGID.EQ.1) GO TO 240
C
C     N O N - R I G I D   A C C E L E R A T I O N S
C
C VERTICAL ACCELERATIONS , UPPER MASS OF UPPER BODY
      ZDSUB1 = ACC1S
      ZDVUB1 = ACC1V
      ZDPUB1 = ACC1P
C LOWER MASS OF UPPER BODY
      ZDSUB2 = ACC1S
      ZDVUB2 = ACC1V
      ZDPUB2 = ACC1P
C LATERAL ACCELERATIONS
      YDSUB1 = ACC7S
      YDVUB1 = ACC7V
      YDPUB1 = ACC7P
      YDSUB2 = ACC13S
      YDVUB2 = ACC13V
      YDPUB2 = ACC13P
C LONGITUDINAL ACCELERATIONS
      XDSUB1 = ACC6S
      XDVUB1 = ACC6V
      XDPUB1 = ACC6P
      XDSUB2 = ACC12S
      XDVUB2 = ACC12V
      XDPUB2 = ACC12P
      XDPUB1 =XDPUB1 * 57.29578
      YDPUB1 =YDPUB1 * 57.29578
      ZDPUB1 =ZDPUB1 * 57.29578
      XDPUB2= XDPUB2 * 57.29578
      YDPUB2= YDPUB2 * 57.29578
      ZDPUB2= ZDPUB2 * 57.29578
C
C PITCH ACCELERATIONS
C
  240 CONTINUE
      IF (IRIGID.EQ.1) GO TO 250
      XCOM1  = ACC2V*SIN(ACC2P) - ACC3V*SIN(ACC3P)
      YCOM1  = ACC2V*COS(ACC2P) - ACC3V*COS(ACC3P)
      PAUB1P = ATAN2(XCOM1,YCOM1)
      PAUB1V = SQRT(XCOM1**2 +YCOM1**2) /(XA3-XA2)*386.
      PAUB1S = (ACC2S-ACC3S)/(XA3-XA2)*386.
  250 CONTINUE
      XCOM2  = ACC8V*SIN(ACC8P) - ACC9V*SIN(ACC9P)
      YCOM2  = ACC8V*COS(ACC8P) - ACC9V*COS(ACC9P)
      PAUB2P = ATAN2(XCOM2,YCOM2)
      PAUB2V = SQRT(XCOM2**2 + YCOM2**2)/ (XA9-XA8)*386.
      PAUB2S = (ACC8S-ACC9S)/(XA9-XA8)*386.
C
C  ROLL ACCELERATIONS
```

```
1        1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0   U1005 CD COUNT

C                                                                         IRBS3970
      IF (IRIGID.EQ.1) GO TO 260                                          IRBS3980
      XCOM3  = ACC5V*SIN(ACC5P) - ACC4V*SIN(ACC4P)                        IRBS3990
      YCOM3  = ACC5V*COS(ACC5P) - ACC4V*COS(ACC4P)                        IRBS4000
      RAUB1P = ATAN2(XCOM3,YCOM3)                                         IRBS4010
      RAUB1V = SQRT(XCOM3**2 + YCOM3**2)/ (YA5-YA4)*386.                  IRBS4020
      RAUB1S =(ACC5S-ACC4S)/(YA5-YA4)*386.                                IRBS4030
  260 CONTINUE                                                            IRBS4040
      XCOM4  = ACC11V*SIN(ACC11P)-ACC10V*SIN(ACC10P)                      IRBS4050
      YCOM4  = ACC11V*COS(ACC11P)-ACC10V*COS(ACC10P)                      IRBS4060
      RAUB2P = ATAN2(XCOM4,YCOM4)                                         IRBS4070
      RAUB2V = SQRT(XCOM4**2 + YCOM4**2)/ (YA11-YA10)*386.                IRBS4080
      RAUB2S = (ACC11S-ACC10S)/ (YA11-YA10)*386.                          IRBS4090
      IF (IDEBUG.EQ.0) GO TO 270                                          IRBS4140
      WRITE (6,280)XCOM1,YCOM1                                            IRBS4150
      WRITE (6,290)XCOM2,YCOM2                                            IRBS4160
      WRITE (6,300)XCOM3,YCOM3                                            IRBS4170
      WRITE (6,310)XCOM4,YCOM4                                            IRBS4180
  270 CONTINUE                                                            IRBS4190
  280 FORMAT('  XCOM1= ',F12.4,'  YCOM1=',F12.4)                          IRBS4200
  290 FORMAT('  XCOM2= ',F12.4,'  YCOM2=',F12.4)                          IRBS4210
  300 FORMAT('  XCOM3= ',F12.4,'  YCOM3=',F12.4)                          IRBS4220
  310 FORMAT('  XCOM4= ',F12.4,'  YCOM4=',F12.4)                          IRBS4230
C
C    MODIFICATIONS TO TAKE INTO ACCOUNT NON-ALIGNMENT OF ACCELEROMETERS.
C
C    JUST FOR NON-RIGID CASE
C
C
      IF(IRIGID.EQ.1) GO TO 271
C
C    UPPER PART OF UPPER BODY.    PITCH.
C
      IF(ZA3-ZA2) 2000,3000,2000
 3000 IF(ZA3-ZUB1)2000,2001,2000
C
 2000 CONTINUE
      DELTX3 = XA3 - XUB1
      DELTX2 = XUB1- XA2
      DELTZ3 = ZA3 - ZUB1
      DELTZ2 = ZUB1- ZA2
      ANGLE3 = ATAN2(DELTZ3,DELTX3)
      ANGLE2 = ATAN2(DELTZ2,DELTX2)
      RAD3   = SQRT(DELTX3**2 + DELTZ3**2)
      RAD2   = SQRT(DELTX2**2 + DELTZ2**2)
      PAUB1V = 386. * SQRT(XCOM1**2 + YCOM1**2) / (RAD2* COS(ANGLE2)
     *         + RAD3* COS(ANGLE3))
      PAUB1S = 386. * (ACC2S - ACC3S) / (RAD2*COS(ANGLE2) +
     *                                   RAD3*COS(ANGLE3) )
C
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0    U1005 CD COUNT

 2001 CONTINUE
      IF(ZA6-ZUB1) 3001,2002,3001
 3001 CONTINUE
      DELTX6 = XA6 - XUB1
      DELTZ6 = ZA6 - ZUB1
      ANGLE6 = ATAN2(DELTZ6,DELTX6)
      RAD6   = SQRT(DELTZ6**2 + DELTX6**2)
      XDSUB1 = ACC6S - (RAD6*PAUB1S*SIN(ANGLE6)) /386.
      XDUREU = ACC6V*COS(ACC6P) - (RAD6*PAUB1V*SIN(ANGLE6))
     *                          * COS(PAUB1P) / 386.
      XDUIMU = ACC6V*SIN(ACC6P) - (RAD6*PAUB1V*SIN(ANGLE6))
     *                          * SIN(PAUB1P) / 386.
      XDPUB1 = ATAN2(XDUIMU,XDUREU)*57.29578
      XDVUB1 = SQRT(XDUREU**2 + XDUIMU**2)
C
C   ROLL
C
 2002 CONTINUE
      IF(ZA5-ZA4) 2003,3002,2003
 3002 IF(ZA5-ZUB1)2003,2004,2003
 2003 CONTINUE
C
      DELTY5 = YA5 -YUB1
      DELTY4 = YUB1-YA4
      DELTZ5 = ZA5 -ZUB1
      DELTZ4 = ZUB1-ZA4
      ANGLE5 = ATAN2(DELTZ5,DELTY5)
      ANGLE4 = ATAN2(DELTZ4,DELTY4)
      RAD5   = SQRT(DELTY5**2 + DELTZ5**2)
      RAD4   = SQRT(DELTY4**2 + DELTZ4**2)
      RAUB1V = 386. * SQRT(XCOM3**2 + YCOM3**2) / (RAD5*COS(ANGLE5)
     *         +                                  RAD4*COS(ANGLE4) )
      RAUB1S = 386. * (ACC5S - ACC4S) / (RAD5*COS(ANGLE5)
     *                             +    RAD4*COS(ANGLE4) )
C
 2004 CONTINUE
      IF(ZA7-ZUB1) 3003,2005,3003
 3003 CONTINUE
      DELTY7 = YA7 - YUB1
      DELTZ7 = ZA7 - ZUB1
      ANGLE7 = ATAN2(DELTZ7,DELTY7)
      RAD7   = SQRT(DELTY7**2 + DELTZ7**2)
      YDSUB1 = ACC7S + RAD7*RAUB1S*SIN(ANGLE7) / 386.
      YDUREU = ACC7V*COS(ACC7P) + (RAD7*RAUB1V* SIN(ANGLE7))
     *                        * COS(RAUB1P) /  386.
      YDUIMU = ACC7V*SIN(ACC7P) + (RAD7*RAUB1V*SIN(ANGLE7))
     *                        *  SIN(RAUB1P)  / 386.
      YDPUB1 = ATAN2(YDUIMU,YDUREU)*57.29578
      YDVUB1 = SQRT(YDUREU**2 + YDUIMU **2)
 2005 CONTINUE
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0     U1005 CD COUNT

C
C   LOWER PART OF UPPER BODY  .   PITCH.
C
C
      IF(ZA9-ZA8) 2006,4000,2006
 4000 IF(ZA9-ZUB1)2006,2007,2006
C
 2006 CONTINUE
      DELTX9 = XA9 - XUB2
      DELTX8 = XUB2- XA8
      DELTZ9 = ZA9 - ZUB2
      DELTZ8 = ZUB2- ZA8
      ANGLE9 = ATAN2(DELTZ9,DELTX9)
      ANGLE8 = ATAN2(DELTZ8,DELTX8)
      RAD9   = SQRT(DELTX9**2 + DELTZ9**2)
      RAD8   = SQRT(DELTX8**2 + DELTZ8**2)
      PAUB2V = 386.* SQRT(XCOM2**2 + YCOM2**2) / (RAD8*COS(ANGLE8)
     *                                   + RAD9*COS(ANGLE9) )
      PAUB2S = 386.* (ACC8S-ACC9S) / (RAD8*COS(ANGLE8)
     *                            +  RAD9*COS(ANGLE9) )
C
 2007 CONTINUE
      IF(ZA12 - ZUB2) 4001,2008,4001
 4001 CONTINUE
      DELX12 = XA12 - XUB2
      DELZ12 = ZA12 - ZUB2
      ANGL12 = ATAN2(DELZ12,DELX12)
      RAD12  = SQRT(DELZ12**2 + DELX12**2)
      XDSUB2 = ACC12S - (RAD12 *PAUB2S * SIN(ANGL12) ) / 386.
      XDUREL = ACC12V * COS(ACC12P) - (RAD12*PAUB2V * SIN(ANGL12))
     *                              * COS(PAUB2P)  / 386.
      XDUIML = ACC12V * SIN(ACC12P) - (RAD12*PAUB2V * SIN(ANGL12))
     *                              * SIN(PAUB2P)  / 386.
      XDPUB2 = ATAN2(XDUIML,XDUREL)*57.29578
      XDVUB2 = SQRT(XDUREL**2 + XDUIML **2 )
C
C  ROLL
C
 2008 CONTINUE
      IF(ZA11- ZA10) 2009,4002,2009
 4002 IF(ZA11- ZUB2) 2009,2010,2009
 2009 CONTINUE
C
      DELY11 = YA11 - YUB2
      DELY10 = YUB2 - YA10
      DELZ11 = ZA11 - ZUB2
      DELZ10 = ZUB2 - ZA10
      ANGL11 = ATAN2(DELZ11,DELY11)
      ANGL10 = ATAN2(DELZ10,DELY10)
      RAD11  = SQRT(DELY11**2 + DELZ11**2)
```

```
1       1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0

      RAD10  = SQRT(DELY10**2 + DELZ10**2)
      RAUB2V = 386.* SQRT(XCOM4**2 + YCOM4 **2)/ (RAD11 *COS(ANGL11)
     *                                     +  RAD10 *COS(ANGL10) )
      RAUB2S = 386.* (ACC11S - ACC10S) / (RAD11* COS(ANGL11)
     *                           +  RAD10* COS(ANGL10) )
C
 2010 CONTINUE
      IF(ZA13 - ZUB2) 4003,2011,4003
 4003 CONTINUE
C
      DELY13 = YA13 - YUB2
      DELZ13 = ZA13 - ZUB2
      ANGL13 = ATAN2(DELZ13,DELY13)
      RAD13  = SQRT(DELY13**2 + DELZ13**2)
      YDSUB2 = ACC13S + (RAD13* RAUB2S * SIN(ANGL13)) /386.
      YDUREL = ACC13V * COS(ACC13P) + (RAD13* RAUB2V * SIN(ANGL13))
     *                              * COS(RAUB2P) / 386.
      YDUIML = ACC13V * SIN(ACC13P) + (RAD13* RAUB2V * SIN(ANGL13))
     *                              * SIN(RAUB2P) / 386.
      YDPUB2 = ATAN2(YDUIML,YDUREL)*57.29578
      YDVUB2 = SQRT(YDUREL**2 + YDUIML **2)
C
 2011 CONTINUE
C
 271  CONTINUE
      RAUB1P =RAUB1P * 57.29578                                         IRBS4100
      PAUB1P =PAUB1P * 57.29578                                         IRBS4110
      RAUB2P= RAUB2P * 57.29578                                         IRBS4120
      PAUB2P= PAUB2P * 57.29578                                         IRBS4130
C                                                                       IRBS4240
      IF (IRIGID.EQ.0) GO TO 320                                        IRBS4250
C                                                                       IRBS4260
C     R I G I D   A C C E L E R A T I O N S                             IRBS4270
C                                                                       IRBS4280
      ZDSUB  = ACC1S                                                    IRBS4290
      ZDVUB  = ACC1V                                                    IRBS4300
      ZDPUB  = ACC1P                                                    IRBS4310
      YDSUB  = ACC7S                                                    IRBS4320
      YDVUB  = ACC7V                                                    IRBS4330
      YDPUB  = ACC7P                                                    IRBS4340
      XDSUB  = ACC6S                                                    IRBS4350
      XDVUB  = ACC6V                                                    IRBS4360
      XDPUB  = ACC6P                                                    IRBS4370
      PAUBS  = PAUB2S                                                   IRBS4380
      PAUBV  = PAUB2V                                                   IRBS4390
      PAUBP  = PAUB2P                                                   IRBS4400
      RAUBS  = RAUB2S                                                   IRBS4410
      RAUBV  = RAUB2V                                                   IRBS4420
      RAUBP  = RAUB2P                                                   IRBS4430
      XDPUB = XDPUB * 57.29578                                          IRBS4440
```

```
1       1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0        U1005 CD COUNT

      YDPUB = YDPUB * 57.29578                                          IRBS4450   00601
      ZDPUB = ZDPUB * 57.29578                                          IRBS4460   00602
      RAUBP = RAUBP * 57.29578                                          IRBS4470   00603
      PAUBP = PAUBP * 57.29578                                          IRBS4480   00604
C                                                                       IRBS4490   00605
  320 CONTINUE                                                          IRBS4500   00606
C                                                                       IRBS4510   00607
C   PRINT ACCELERATIONS                                                 IRBS4520   00608
C                                                                       IRBS4530   00609
      IF (IDEBUG.EQ.0) GO TO 330                                        IRBS4540   00610
      IF (IRIGID.EQ.0) WRITE (6,700)ZDSUB1,ZDVUB1,ZDPUB1,ZDSUB2,ZDVUB2,ZIRBS4550   00611
     1DPUB2,YDSUB1,YDVUB1,YDPUB1,YDSUB2,YDVUB2,YDPUB2,XDSUB1,XDVUB1,XDPUIRBS4560   00612
     2B1,XDSUB2,XDVUB2,XDPUB2,PAUB1P,PAUB1V,PAUB1S,PAUB2P,PAUB2V,PAUB2S,IRBS4570   00613
     3RAUB1P,RAUB1V,RAUB1S,RAUB2P,RAUB2V,RAUB2S                         IRBS4580   00614
      IF (IRIGID.EQ.1) WRITE (6,710)ZDSUB,ZDVUB,ZDPUB,YDSUB,YDVUB,YDPUB,IRBS4590   00615
     1XDSUB,XDVUB,XDPUB,PAUBS,PAUBV,PAUBP,RAUBS,RAUBV,RAUBP             IRBS4600   00616
  330 CONTINUE                                                          IRBS4610   00617
C                                                                       IRBS4620   00618
C  C A L C U L A T E   I N E R T I A   F O R C E S                      IRBS4630   00619
C                                                                       IRBS4640   00620
      IF (IRIGID.EQ.1) GO TO 340                                        IRBS4650   00621
C                                                                       IRBS4660   00622
C  NON-RIGID                                                            IRBS4670   00623
C                                                                       IRBS4680   00624
C  UPPER MASS OF UPPER BODY                                             IRBS4690   00625
      VIUB1S =  WUB1*ZDSUB1                                             IRBS4700   00626
      VIUB1V =  WUB1*ZDVUB1                                             IRBS4710   00627
      VIUB1P =  ZDPUB1 + 180.                                           IRBS4720   00628
      SIUB1S =  WUB1*YDSUB1                                             IRBS4730   00629
      SIUB1V =  WUB1*YDVUB1                                             IRBS4740   00630
      SIUB1P =  YDPUB1 + 180.                                           IRBS4750   00631
      DIUB1S =  WUB1*XDSUB1                                             IRBS4760   00632
      DIUB1V =  WUB1*XDVUB1                                             IRBS4770   00633
      DIUB1P =  XDPUB1 + 180.                                           IRBS4780   00634
      RIUB1S = IOXUB1*RAUB1S                                            IRBS4790   00635
      RIUB1V = IOXUB1*RAUB1V                                            IRBS4800   00636
      RIUB1P = RAUB1P + 180.                                            IRBS4810   00637
      PIUB1S = IOYUB1*PAUB1S                                            IRBS4820   00638
      PIUB1V = IOYUB1*PAUB1V                                            IRBS4830   00639
      PIUB1P = PAUB1P + 180.                                            IRBS4840   00640
C  LOWER MASS OF UPPER BODY                                             IRBS4850   00641
      VIUB2S = WUB2*ZDSUB2                                              IRBS4860   00642
      VIUB2V = WUB2*ZDVUB2                                              IRBS4870   00643
      VIUB2P = ZDPUB2 + 180.                                            IRBS4880   00644
      SIUB2S = WUB2*YDSUB2                                              IRBS4890   00645
      SIUB2V = WUB2*YDVUB2                                              IRBS4900   00646
      SIUB2P = YDPUB2 + 180.                                            IRBS4910   00647
      DIUB2S = WUB2*XDSUB2                                              IRBS4920   00648
      DIUB2V = WUB2*XDVUB2                                              IRBS4930   00649
      DIUB2P = XDPUB2 + 180.                                            IRBS4940   00650
```

```
1       1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0     U1005 CD COUNT

      RIUB2S = IOXUB2* RAUB2S                                          IRBS4950     00651
      RIUB2V = IOXUB2* RAUB2V                                          IRBS4960     00652
      RIUB2P = RAUB2P + 180.                                           IRBS4970     00653
      PIUB2S = IOYUB2* PAUB2S                                          IRBS4980     00654
      PIUB2V = IOYUB2* PAUB2V                                          IRBS4990     00655
      PIUB2P = PAUB2P  + 180.                                          IRBS5000     00656
C ALLOW VIBRATORY MASS TO BE USED , NOT STEADY MASS                                  00657
      IF(IVERVM.NE.0) VIUB2V=VERVM * ZDVUB2                                         00658
      IF(INPVM .NE.0) SIUB2V=AINPVM* YDVUB2                                         00659
      IF(INPVM .NE.0) DIUB2V=AINPVM* XDVUB2                                         00660
C                                                                      IRBS5010     00661
      GO TO 350                                                        IRBS5020     00662
C                                                                      IRBS5030     00663
C   UPPER BODY AS A RIGID SYSTEM                                       IRBS5040     00664
C                                                                      IRBS5050     00665
  340 CONTINUE                                                         IRBS5060     00666
      VIUBS  = WUB*ZDSUB                                               IRBS5070     00667
      VIUBV  = WUB*ZDVUB                                               IRBS5080     00668
      VIUBP  = ZDPUB + 180.                                            IRBS5090     00669
      SIUBS  = WUB*YDSUB                                               IRBS5100     00670
      SIUBV  = WUB*YDVUB                                               IRBS5110     00671
      SIUBP  = YDPUB + 180.                                            IRBS5120     00672
      DIUBS  = WUB*XDSUB                                               IRBS5130     00673
      DIUBV  = WUB*XDVUB                                               IRBS5140     00674
      DIUBP  = XDPUB  + 180.                                           IRBS5150     00675
      RIUBS  = IOXUB*RAUBS                                             IRBS5160     00676
      RIUBV  = IOXUB*RAUBV                                             IRBS5170     00677
      RIUBP  = RAUBP  + 180.                                           IRBS5180     00678
      PIUBS  = IOYUB*PAUBS                                             IRBS5190     00679
      PIUBV  = IOYUB*PAUBV                                             IRBS5200     00680
      PIUBP  = PAUBP  + 180.                                           IRBS5210     00681
C ALLOW VIBRATORY MASS TO BE USED                                                   00682
      IF(IVERVM.NE.0) VIUBV =VERVM * ZDVUB                                          00683
      IF(INPVM .NE.0) SIUBV =AINPVM* YDVUB                                          00684
      IF(INPVM .NE.0) DIUBV =AINPVM* XDVUB                                          00685
C                                                                      IRBS5220     00686
  350 CONTINUE                                                         IRBS5230     00687
C                                                                      IRBS5240     00688
C  SET UP VECTORS FROM RECORDED DATA                                   IRBS5250     00689
C                                                                      IRBS5260     00690
      PHV(1) = P1HV                                                    IRBS5270     00691
      PHV(2) = P2HV                                                    IRBS5280     00692
      PHV(3) = P3HV                                                    IRBS5290     00693
      PLV(1) = P1LV                                                    IRBS5300     00694
      PLV(2) = P2LV                                                    IRBS5310     00695
      PLV(3) = P3LV                                                    IRBS5320     00696
      PHS(1) = P1HS                                                    IRBS5330     00697
      PHS(2) = P2HS                                                    IRBS5340     00698
      PHS(3) = P3HS                                                    IRBS5350     00699
      PLS(1) = P1LS                                                    IRBS5360     00700
```

```
1       1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0      U1005 CD COUNT

      PLS(2) = P2LS                                                         IRBS5370     00701
      PLS(3) = P3LS                                                         IRBS5380     00702
      PHP(1) = P1HP                                                         IRBS5390     00703
      PHP(2) = P2HP                                                         IRBS5400     00704
      PHP(3) = P3HP                                                         IRBS5410     00705
      PLP(1) = P1LP                                                         IRBS5420     00706
      PLP(2) = P2LP                                                         IRBS5430     00707
      PLP(3) = P3LP                                                         IRBS5440     00708
C                                                                           IRBS5450     00709
C    C A L C U L A T I O N S   P E R   I S O L A T O R                      IRBS5460     00710
C                                                                           IRBS5470     00711
      DO 380 I=1,3                                                          IRBS5480     00712
      FHV(I) = AH * PHV(I)                                                  IRBS5490     00713
      FLV(I) = AL * PLV(I)                                                  IRBS5500     00714
      IF (IDEBUG.EQ.0) GO TO 370                                            IRBS5510     00715
      WRITE (6,360)AH,AL,PHV(I),PLV(I),FHV(I),FLV(I),PHP(I),PLP(I)          IRBS5520     00716
  360 FORMAT(' ***',8F12.4)                                                 IRBS5530     00717
  370 CONTINUE                                                              IRBS5540     00718
      XX(I)  = FHV(I)*SIN(PHP(I)) - FLV(I)*SIN(PLP(I))                      IRBS5550     00719
      YY(I)  = FHV(I)*COS(PHP(I)) - FLV(I)*COS(PLP(I))                      IRBS5560     00720
      FIV(I) = SQRT(XX(I)**2 + YY(I)**2)                                    IRBS5570     00721
      FIVP(I)= ATAN2(XX(I),YY(I))                                           IRBS5580     00722
      FIVPX(I)=FIVP(I) * 57.29578                                           IRBS5590     00723
C                                                                           IRBS5600     00724
C    CORRECTED STEADY LOADS PER ISOLATOR                                    IRBS5610     00725
C                                                                           IRBS5620     00726
      FIM(I) = PHS(I)*AH - PLS(I)*AL                                        IRBS5630     00727
      CALL CIP(IERR(I),NC,LOC,X,Y,SELLIN,FIM(I),ERROR(I),DM1,DM2,DM3,2)     IRBS5640     00728
      FITS(I)= FIM(I)+ ERROR(I)                                             IRBS5650     00729
C                                                                           IRBS5660     00730
C    MEASURING SYSTEM LOADS                                                 IRBS5670     00731
C                                                                           IRBS5680     00732
      FIT(I) = FITS(I) + FIV(I)*COS(FIVP(I))                                IRBS5690     00733
C                                                                           IRBS5700     00734
  380 CONTINUE                                                              IRBS5710     00735
      IF (IDEBUG.EQ.0) GO TO 400                                            IRBS5720     00736
      WRITE (6,390)(XX(I),YY(I),FIV(I),FIVPX(I),I=1,3)                      IRBS5730     00737
  390 FORMAT(2X,4F12.3)                                                     IRBS5740     00738
  400 CONTINUE                                                              IRBS5750     00739
C                                                                           IRBS5760     00740
      FLCT(1)= FLC1TS + FLC1TV * COS(FLC1TP)                                IRBS5770     00741
      FLCT(2)= FLC2TS + FLC2TV * COS(FLC2TP)                                IRBS5780     00742
      FLCT(3)= FLC3TS + FLC3TV * COS(FLC3TP)                                IRBS5790     00743
      FLCT(4)= FLC4TS + FLC4TV * COS(FLC4TP)                                IRBS5800     00744
C                                                                           IRBS5810     00745
C     CALCULATION OF SHAKER FORCE (MEASURED)                                IRBS5820     00746
C                                                                           IRBS5830     00747
      VIUBP  = VIUBP  / 57.29578                                            IRBS5840     00748
      DIUBP  = DIUBP  / 57.29578                                            IRBS5850     00749
      SIUBP  = SIUBP  / 57.29578                                            IRBS5860     00750
```

```
1       1         2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0    U1005 CD COUNT
      VIUB1P = VIUB1P / 57.29578                                        IRBS5870
      VIUB2P = VIUB2P / 57.29578                                        IRBS5880
      DIUB1P = DIUB1P / 57.29578                                        IRBS5890
      DIUB2P = DIUB2P / 57.29578                                        IRBS5900
      SIUB1P = SIUB1P / 57.29578                                        IRBS5910
      SIUB2P = SIUB2P / 57.29578                                        IRBS5920
C VERTICAL                                                              IRBS5930
      RIG1   = VIUBV * COS(VIUBP)                                       IRBS5940
      IF(IRIGID.NE.1) RIG1= VIUB1V*COS(VIUB1P)+VIUB2V*COS(VIUB2P)       IRBS5950
      RIG2   = VIUBV * SIN(VIUBP)                                       IRBS5960
      IF(IRIGID.NE.1) RIG2= VIUB1V*SIN(VIUB1P)+VIUB2V*SIN(VIUB2P)       IRBS5970
C                                                                       IRBS5980
      IF (IDEBUG.EQ.0) GO TO 410                                        IRBS5990
      WRITE (6,420)RIG1,RIG2,BETA,DRV,DRP,(FIV(I),I=1,3),(FIVP(I),I=1,3)IRBS6000
  410 CONTINUE                                                          IRBS6010
  420 FORMAT(///'  RIG1 = ', F12.4 /                                    IRBS6020
     1            '  RIG2 = ', F12.4 /                                  IRBS6030
     2            '  BETA = ', F12.4 /                                  IRBS6040
     3            '  DRV  = ', F12.4 /                                  IRBS6050
     4            '  DRP  = ', F12.4 /                                  IRBS6060
     5            '  FIV  = ',3F12.4 /                                  IRBS6070
     6            '  FIVP = ',3F12.4 )                                  IRBS6080
      SBETA = SIN(BETA)                                                 IRBS6090
      FSZR   = DRV*SBETA*COS(DRP) - RIG1                                IRBS6100
     1       + FIV(1)*COS(FIVP(1))+FIV(2)*COS(FIVP(2))                  IRBS6110
     2       + FIV(3)*COS(FIVP(3))                                      IRBS6120
      FSZI   = DRV*SBETA*SIN(DRP) - RIG2                                IRBS6130
     1       + FIV(1)*SIN(FIVP(1))+FIV(2)*SIN(FIVP(2))                  IRBS6140
     2       + FIV(3)*SIN(FIVP(3))                                      IRBS6150
      FSZ    = SQRT(FSZR**2 + FSZI**2)                                  IRBS6160
      PHIFSZ= ATAN2(FSZI,FSZR)                                          IRBS6170
C  LONGITUDINAL                                                         IRBS6180
      RIG1   = DIUBV * COS(DIUBP)                                       IRBS6190
      IF(IRIGID.NE.1) RIG1=DIUB1V*COS(DIUB1P)+DIUB2V*COS(DIUB2P)        IRBS6200
      RIG2   = DIUBV * SIN(DIUBP)                                       IRBS6210
      IF(IRIGID.NE.1) RIG2=DIUB1V*SIN(DIUB1P)+DIUB2V*SIN(DIUB2P)        IRBS6220
C                                                                       IRBS6230
      CBETA = COS(BETA)                                                 IRBS6240
      SALPHA= SIN(ALPHA)                                                IRBS6250
C                                                                       IRBS6260
      FSXR   =-DRV*CBETA*COS(DRP) - RIG1                                IRBS6270
     1         -TAP1V*SALPHA*COS(TAP1P) + TAP2V*SALPHA*COS(TAP2P)       IRBS6280
     2         -FLC3TV*COS(FLC3TP)       + FLC1TV*COS(FLC1TP)           IRBS6290
      FSXI   =-DRV*CBETA*SIN(DRP) - RIG2                                IRBS6300
     1         -TAP1V*SALPHA*SIN(TAP1P) + TAP2V*SALPHA*SIN(TAP2P)       IRBS6310
     2         -FLC3TV*SIN(FLC3TP)       + FLC1TV*SIN(FLC1TP)           IRBS6320
      FSX    = SQRT(FSXR**2 + FSXI**2)                                  IRBS6330
      PHIFSX= ATAN2(FSXI,FSXR)                                          IRBS6340
C LATERAL                                                               IRBS6350
      RIG2   = SIUBV * SIN(SIUBP)                                       IRBS6360
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0   U1005 CD COUNT

      IF(IRIGID.NE.1) RIG2=SIUB1V*SIN(SIUB1P)+SIUB2V*SIN(SIUB2P)              IRBS6370
      RIG1  = SIUBV * COS(SIUBP)                                              IRBS6380
      IF(IRIGID.NE.1) RIG1=SIUB1V*COS(SIUB1P)+SIUB2V*COS(SIUB2P)              IRBS6390
C                                                                             IRBS6400
      IF (IDEBUG.EQ.0) GO TO 430                                              IRBS6410
      WRITE (6,440)RIG1,RIG2,TAP1V,ALPHA,TAP1P,TAP2V,TAP2P,FLC2TV,FLC2TPIRBS6420
     1,FLC4TV,FLC4TP                                                          IRBS6430
  430 CONTINUE                                                                IRBS6440
  440 FORMAT(///'  RIG1 = ',F12.4/                                            IRBS6450
     1          '  RIG2 = ',F12.4/                                            IRBS6460
     2          '  TAP1V= ',F12.4/                                            IRBS6470
     3          '  ALPHA= ',F12.4/                                            IRBS6480
     4          '  TAP1P= ',F12.4/                                            IRBS6490
     5          '  TAP2V= ',F12.4/                                            IRBS6500
     6          '  TAP2P= ',F12.4/                                            IRBS6510
     7          ' FLC2TV= ',F12.4/                                            IRBS6520
     8          ' FLC2TP= ',F12.4/                                            IRBS6530
     9          ' FLC4TV= ',F12.4/                                            IRBS6540
     A          ' FLC4TP= ',F12.4 )                                           IRBS6550
      CALPHA= COS(ALPHA)                                                      IRBS6560
C                                                                             IRBS6570
      FSYR  = -TAP1V*CALPHA*COS(TAP1P)+ TAP2V*CALPHA*COS(TAP2P)               IRBS6580
     1        -FLC2TV*COS(FLC2TP)      + FLC4TV*COS(FLC4TP)                   IRBS6590
     2        -RIG1                                                           IRBS6600
      FSYI  = -TAP1V*CALPHA*SIN(TAP1P)+ TAP2V*CALPHA*SIN(TAP2P)               IRBS6610
     1        -FLC2TV*SIN(FLC2TP)      + FLC4TV*SIN(FLC4TP)                   IRBS6620
     2        -RIG2                                                           IRBS6630
      FSY   = SQRT(FSYR**2 + FSYI**2)                                         IRBS6640
      PHIFSY= ATAN2(FSYI,FSYR)                                                IRBS6650
      IF (IDEBUG.EQ.0) GO TO 450                                              IRBS6660
      WRITE (6,460)FSZR,FSZI,FSXR,FSXI,FSYR,FSYI                              IRBS6670
  450 CONTINUE                                                                IRBS6680
  460 FORMAT(///' FSZR  = ', F12.4 /                                          IRBS6690
     1          ' FSZI  = ', F12.4 /                                          IRBS6700
     2          ' FSXR  = ', F12.4 /                                          IRBS6710
     3          ' FSXI  = ', F12.4 /                                          IRBS6720
     4          ' FSYR  = ', F12.4 /                                          IRBS6730
     5          ' FSYI  = ', F12.4 )                                          IRBS6740
      VIUBP  = VIUBP  * 57.29578                                              IRBS6750
      DIUBP  = DIUBP  * 57.29578                                              IRBS6760
      SIUBP  = SIUBP  * 57.29578                                              IRBS6770
      VIUB1P = VIUB1P * 57.29578                                              IRBS6780
      VIUB2P = VIUB2P * 57.29578                                              IRBS6790
      DIUB1P = DIUB1P * 57.29578                                              IRBS6800
      DIUB2P = DIUB2P * 57.29578                                              IRBS6810
      SIUB1P = SIUB1P * 57.29578                                              IRBS6820
      SIUB2P = SIUB2P * 57.29578                                              IRBS6830
      THTLON = THTLON / 57.29578                                              IRBS6840
      THTLAT = THTLAT / 57.29578                                              IRBS6850
      PHIFSZ = PHIFSZ * 57.29578                                              IRBS6860
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0
      PHIFSX = PHIFSX * 57.29578                                        IRBS6870
      PHIFSY = PHIFSY * 57.29578                                        IRBS6880
C                                                                       IRBS6890
C  CALCULATION OF SHAKER FORCE (APPLIED)                                IRBS6900
C                                                                       IRBS6910
      FSZA   = SF*COS(THTLON)*COS(THTLAT)                               IRBS6920
      FSYA   = SF*SIN(THTLAT)                                           IRBS6930
      FSXA   = SF*SIN(THTLON)                                           IRBS6940
      FIFSZA= 0.                                                        IRBS6950
      FIFSYA= 0.                                                        IRBS6960
      FIFSXA= 0.                                                        IRBS6970
      IF (ITYPE.EQ.0) GO TO 510                                         IRBS6980
C                                                                       IRBS6990
C   V I B R A T O R Y   P R I N T O U T                                 IRBS7000
C                                                                       IRBS7010
      WRITE (6,720)                                                     IRBS7020
      IF (IRIGID.EQ.1) GO TO 470                                        IRBS7030
C                                                                       IRBS7040
C   NON-RIGID ACCELERATIONS                                             IRBS7050
C                                                                       IRBS7060
      WRITE (6,730)XDSUB1,YDSUB1,ZDSUB1,RAUB1S,PAUB1S,XDVUB1,YDVUB1,ZDVUIRBS7070
     1B1,RAUB1V,PAUB1V,XDPUB1,YDPUB1,ZDPUB1,RAUB1P,PAUB1P               IRBS7080
      WRITE (6,740)XDSUB2,YDSUB2,ZDSUB2,RAUB2S,PAUB2S,XDVUB2,YDVUB2,ZDVUIRBS7090
     1B2,RAUB2V,PAUB2V,XDPUB2,YDPUB2,ZDPUB2,RAUB2P,PAUB2P               IRBS7100
      GO TO 480                                                         IRBS7110
  470 CONTINUE                                                          IRBS7120
C                                                                       IRBS7130
C   RIGID ACCELERATIONS                                                 IRBS7140
C                                                                       IRBS7150
      WRITE (6,750)XDSUB,YDSUB,ZDSUB,RAUBS,PAUBS,XDVUB,YDVUB,ZDVUB,RAUBVIRBS7160
     1,PAUBV,XDPUB,YDPUB,ZDPUB,RAUBP,PAUBP                              IRBS7170
  480 CONTINUE                                                          IRBS7180
C                                                                       IRBS7190
      WRITE (6,760)                                                     IRBS7200
      IF(IVERVM.NE.0.OR.INPVM.NE.0)  WRITE(6,761)
 761  FORMAT(10X,'(VIBRATORY MASS USED)' / )
      IF (IRIGID.EQ.1) GO TO 490                                        IRBS7210
C                                                                       IRBS7220
C   NON-RIGID INERTIA FORCES                                            IRBS7230
C                                                                       IRBS7240
      WRITE (6,730)DIUB1S,SIUB1S,VIUB1S,RIUB1S,PIUB1S,DIUB1V,SIUB1V,VIUBIRBS7250
     11V,RIUB1V,PIUB1V,DIUB1P,SIUB1P,VIUB1P,RIUB1P,PIUB1P               IRBS7260
      WRITE (6,740)DIUB2S,SIUB2S,VIUB2S,RIUB2S,PIUB2S,DIUB2V,SIUB2V,VIUBIRBS7270
     12V,RIUB2V,PIUB2V,DIUB2P,SIUB2P,VIUB2P,RIUB2P,PIUB2P               IRBS7280
      GO TO 500                                                         IRBS7290
  490 CONTINUE                                                          IRBS7300
C                                                                       IRBS7310
C   RIGID INERTIA FORCES                                                IRBS7320
C                                                                       IRBS7330
      WRITE (6,750)DIUBS,SIUBS,VIUBS,RIUBS,PIUBS,DIUBV,SIUBV,VIUBV,RIUBVIRBS7340
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0   U1005 CD COUNT

     1,PIUBV,DIUBP,SIUBP,VIUBP,RIUBP,PIUBP                               IRBS7350
  500 CONTINUE                                                           IRBS7360
C                                                                        IRBS7370
C   ISOLATOR LOADS                                                       IRBS7380
C                                                                        IRBS7390
      WRITE (6,770)FITS,FIV,FIVPX                                        IRBS7400
C                                                                        IRBS7410
C   V I B R A T O R Y   O U T P U T                                      IRBS7420
C                                                                        IRBS7430
      WRITE (6,780)                                                      IRBS7440
      WRITE (6,790)DAM,SAM,VAM,MXAM,MYAM,MZAM,DAA,SAA,VAA,MXAA,MYAA,MZAAIRBS7450
     1,DAC,SAC,VAC,MXAC,MYAC,MZAC                                        IRBS7460
      WRITE (6,800)                                                      IRBS7470
      WRITE (6,810)FSZA,FIFSZA,FSYA,FIFSYA,FSXA,FIFSXA,FSZ,PHIFSZ,FSY,PHIRBS7480
     1IFSY,FSX,PHIFSX                                                    IRBS7490
C                                                                        IRBS7500
  510 CONTINUE                                                           IRBS7510
      IF (IEND.EQ.0) GO TO 90                                            IRBS7520
      IF (IEND.EQ.1) GO TO 40                                            IRBS7530
      IF(IEND.EQ.-1)STOP                                                 IRBS7540
C                                                                        IRBS7550
C                                                                        IRBS7560
  520 FORMAT(///60X,'MASS DATA'/60X,9('-')///                            IRBS7570
     1'                        UPPER PART OF         LOWER PART OF      TOTAIRBS7580
     2L UPPER BODY       LOWER BODY        TOTAL AIRCRAFT              '//IRBS7590
     3'                        LOWER BODY            LOWER BODY         '/)IRBS7600
  530 FORMAT(10X,'W ',8X,5(4X,F12.3,4X) /                                IRBS7610
     1          10X,'X ',8X,5(4X,F12.3,4X) /                             IRBS7620
     2          10X,'Y ',8X,5(4X,F12.3,4X) /                             IRBS7630
     3          10X,'Z ',8X,5(4X,F12.3,4X) /                             IRBS7640
     4          10X,'IX',8X,5(4X,F12.3,4X) /                             IRBS7650
     5          10X,'IY',8X,5(4X,F12.3,4X) /  )                          IRBS7660
  540 FORMAT(///60X,'GEOMETRY'/60X,8('-')//                              IRBS7670
     1  30X,'NO.',15X,'X',20X,'Y',19X,'Z',17X,'ANGLE' //                 IRBS7680
     2  10X,'ISOLATORS:'/ )                                              IRBS7690
  550 FORMAT( 30X,'1',9X, 2(4X,F12.3,4X) /                               IRBS7700
     1            30X,'2',9X, 2(4X,F12.3,4X) /                           IRBS7710
     2            30X,'3',9X, 2(4X,F12.3,4X) /  )                        IRBS7720
  560 FORMAT(// 10X,'LOAD CELLS (MEASURING) :'/ )                        IRBS7730
  570 FORMAT( 30X,'1',9X,3(4X,F12.3,4X) /                                IRBS7740
     1            30X,'2',9X,3(4X,F12.3,4X) /                            IRBS7750
     2            30X,'3',9X,3(4X,F12.3,4X) /                            IRBS7760
     3            30X,'4',9X,3(4X,F12.3,4X) / )                          IRBS7770
  580 FORMAT(// 10X,'LOAD CELLS (TORQUE APP):'/ )                        IRBS7780
  590 FORMAT( 30X,'1',9X,4(4X,F12.3,4X) /                                IRBS7790
     1            30X,'2',9X,4(4X,F12.3,4X) / )                          IRBS7800
  600 FORMAT(// 10X,'ACCELEROMETERS: ',22X,'X',20X,'Y',19X,'Z',17X,      IRBS7810
     1 'ANGLE' /)                                                        IRBS7820
  610 FORMAT(// 10X,'PROPULSIVE FORCE:' /)                               IRBS7830
  620 FORMAT( 29X,I2,9X,3(4X,F12.3,4X))                                  IRBS7840
```

```
1        1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0     U1005 CD COUNT

  630 FORMAT( 40X, 4(4X,F12.3,4X) /)
  640 FORMAT(// 10X,'SHAKER FORCE:' /
     1  40X, 3(4X,F12.3,4X))
  650 FORMAT(// 10X,'CORELLATION POINT'/
     1 40X, 3(4X,F12.3,4X) /)
  660 FORMAT(///50X,'ISOLATOR CHARACTERISTICS'/
     1          50X,'-------- ---------------'///
     2 10X,'PRECHARGE , HIGH SIDE = ',F12.3,
     3 14X,'AIR VOLUME REACTION SURFACE , HIGH SIDE = ',F12.3 /
     4 10X,'PRECHARGE , LOW  SIDE = ',F12.3,
     5 14X,'AIR VOLUME REACTION SURFACE , LOW  SIDE = ',F12.3 /
     6 10X,'GAIN                   = ',F12.3,
     7 14X,'DAMPING                                  = ',F12.3 / )
  670 FORMAT(
     1 10X,'SHAKER FORCE           = ',F12.3,
     2 14X,'LONGITUDINAL ANGLE                       = ',F12.3 /
     3 10X,'FREQUENCY              = ',F12.3,
     4 14X,'LATERAL ANGLE                            = ',F12.3 /)
  680 FORMAT(///50X,'PROCESSED DATA'/50X,14('-')//
     1 5X,'EXTERNAL APPLIED LOADS AT A '//
     2 2X,'V   ',F12.3,4X,'S   ',F12.3,4X,'D   ',F12.3,
     3 4X,'MX  ',F12.3,4X,'MY  ',F12.3,4X,'MZ  ',F12.3  ///
     4 5X,'CORRECTED ISOLATOR LOADS' //
     5 2X,'FI1 ',F12.3,4X,'FI2 ',F12.3,4X,'FI3 ',F12.3)
  690 FORMAT(///51X,'OUTPUT'/51X,6('-')//
     1 5X,'MEASURING SYSTEM LOADS AT A'//
     2 2X,'V    ',F12.3,4X,'S    ',F12.3,4X,'D    ',F12.3,
     3 4X,'MX   ',F12.3,4X,'MY   ',F12.3,4X,'MZ   ',F12.3 //
     4 5X,'TOTAL APPLIED LOADS AT A '//
     5 2X,'V    ',F12.3,4X,'S    ',F12.3,4X,'D    ',F12.3,
     6 4X,'MX   ',F12.3,4X,'MY   ',F12.3,4X,'MZ   ',F12.3 //
     7 5X,'CALCULATED EXTERNAL LOADS'//
     8 2X,'V    ',F12.3,4X,'S    ',F12.3,4X,'D    ',F12.3,
     9 4X,'MX   ',F12.3,4X,'MY   ',F12.3,4X,'MZ   ',F12.3   )
  700 FORMAT(/// (6(5X,F12.3,3X)/))
  710 FORMAT(/// (6(5X,F12.3,3X)/))
  720 FORMAT(1H1,59X,'PROCESSED DATA'/60X,14('-')///
     1 10X,'ACCELERATIONS:',25X,'X',17X,'Y',17X,'Z',15X,'ROLL',14X,
     2 'PITCH' / )
  730 FORMAT( 10X,'UPPER PART OF UPPER BODY'/
     1          25X,'STEADY          ',5(3X,F12.3,3X) /
     2          25X,'VIBRATORY       ',5(3X,F12.3,3X) /
     3          25X,'PHASE           ',5(3X,F12.3,3X) / )
  740 FORMAT( 10X,'LOWER PART OF UPPER BODY'/
     1          25X,'STEADY          ',5(3X,F12.3,3X) /
     2          25X,'VIBRATORY       ',5(3X,F12.3,3X) /
     3          25X,'PHASE           ',5(3X,F12.3,3X) / )
  750 FORMAT( 10X,'UPPER BODY' /
     1          25X,'STEADY          ',5(3X,F12.3,3X)  /
     2          25X,'VIBRATORY       ',5(3X,F12.3,3X)  /
```

```
1       1       2         3         4         5         6         7         8
........0.........0.........0.........0.........0.........0.........0.........0    U1005 CD COUNT

     3          25X,'PHASE          ',5(3X,F12.3,3X)  / )             IRBS8350    01001
  760 FORMAT(/// 10X,'INERTIA FORCES:',24X,'X',17X,'Y',17X,'Z',16X,   IRBS8360    01002
     1 'MX',16X,'MY'  /)                                              IRBS8370    01003
  770 FORMAT(/// 10X,'ISOLATOR LOADS:',22X,'NO.1',31X,'NO.2',31X,'NO.3'  IRBS8380  01004
     1 //                                                             IRBS8390    01005
     2          25X,'STEADY         ',2(3X,F12.3,21X),3X,F12.3   /    IRBS8400    01006
     3          25X,'VIBRATORY      ',2(3X,F12.3,21X),3X,F12.3   /    IRBS8410    01007
     4          25X,'PHASE          ',2(3X,F12.3,21X),3X,F12.3   / )  IRBS8420    01008
  780 FORMAT(1H1,59X,'OUTPUT'/60X,6('-') ///                          IRBS8430    01009
     1 10X,'STEADY LOADS AT POINT A:',5X,'X',16X,'Y',16X,'Z',         IRBS8440    01010
     2 15X,'MX',15X,'MY',15X,'MZ' /)                                  IRBS8450    01011
  790 FORMAT( 10X,'MEASURED      ',6X,6(3X,F12.3,2X) /                IRBS8460    01012
     1          10X,'APPLIED       ',6X,6(3X,F12.3,2X) /              IRBS8470    01013
     2          10X,'ROTOR-MEASURED',6X,6(3X,F12.3,2X) /              IRBS8480    01014
     3          10X,'ROTOR-APPLIED ',6X,6(3X,F12.3,2X) / )            IRBS8490    01015
  800 FORMAT(/// 50X,'VIBRATORY ROTOR HEAD FORCES' //                 IRBS8500    01016
     1 40X,'VERTICAL(Z)',23X,'LATERAL(Y)',21X,'LONGITUDINAL(X)'/      IRBS8510    01017
     2 30X,3( 3X,'AMPLITUDE',11X,'PHASE',6X) / )                      IRBS8520    01018
  810 FORMAT( 10X,'APPLIED       ',6X,6(3X,F12.3,2X) /                IRBS8530    01019
     1          10X,'MEASURED      ',6X,6(3X,F12.3,2X) / )            IRBS8540    01020
C                                                                     IRBS8550    01021
C                                                                     IRBS8560    01022
      STOP                                                            IRBS8570    01023
      END                                                             IRBS8580    01024
```

APPENDIX III-C

Sample Test Cases

ACTIVE ISOLATOR FULL SCALE SHAKE TEST

PREPARED BY J.DEFELICE

CHECKED BY

DATE JAN.3,1973

VIBRATORY EXCITATION--LONGITUDINAL 500 LB FORCE 30HZ (RUN 6C)

MASS DATA

	UPPER PART OF LOWER BODY	LOWER PART OF LOWER BODY	TOTAL UPPER BODY	LOWER BODY	TOTAL AIRCRAFT
W	4808.000	3004.700	7812.700	26187.300	34000.000
X	337.160	335.650	336.579	336.350	336.403
Y	.000	.000	.000	.000	.000
Z	257.120	199.980	235.144	129.820	154.022
IX	2060.000	1522.000	19222.750	113336.000	305494.310
IY	2372.000	1980.000	20003.673	1720534.000	1913473.800

GEOMETRY

	NO.	X	Y	Z	ANGLE
ISOLATORS:					
	1	306.600	.000		
	2	356.100	25.200		
	3	356.100	-25.200		
LOAD CELLS (MEASURING) :					
	1	324.000	-20.000	197.125	
	2	322.000	18.300	197.125	
	3	363.600	20.000	197.125	
	4	363.600	-19.000	197.125	
LOAD CELLS (TORQUE APP):					
	1	335.700	26.200	197.125	65.000
	2	348.300	-26.200	197.125	65.000

ACCELEROMETERS:	X	Y	Z	ANGLE
1	337.000	.000	270.000	
2	324.000	.000	253.900	
3	349.000	.000	256.100	
4	337.000	-14.000	255.000	
5	337.000	14.000	255.000	
6	337.000	14.000	255.000	
7	337.000	14.000	255.000	
8	326.000	.000	202.000	
9	359.000	.000	200.000	
10	336.000	-18.000	200.000	
11	336.000	21.000	200.000	
12	336.000	21.000	200.000	
13	336.000	21.000	200.000	
PROPULSIVE FORCE:	370.000	.000	259.700	-1.000
SHAKER FORCE:	335.900	.000	261.900	
CORELLATION POINT	336.400	.000	258.000	

ISOLATOR CHARACTERISTICS
-------- ---------------

PRECHARGE , HIGH SIDE =	300.000	AIR VOLUME REACTION SURFACE , HIGH SIDE =	12.393
PRECHARGE , LOW SIDE =	1100.000	AIR VOLUME REACTION SURFACE , LOW SIDE =	14.193
GAIN =	100.000	DAMPING =	.000
SHAKER FORCE =	500.000	LONGITUDINAL ANGLE =	90.000
FREQUENCY =	30.000	LATERAL ANGLE =	.000

*** D ***

25.200	25.200	60.875	.000	29.800
19.700	-.179	20.000	14.400	20.000
27.200	.700	26.200	11.900	26.200
33.600	1.700			

VIBRATORY LOAD LONGITUDINAL EXCITATION 500 LB FORCE 30HZ (RUN 6C)

RECORDED DATA

ITEM	CHANNEL	STEADY	VIBRATORY	PHASE
DR	1	.000	.000	360.000
TAP1	2	.000	.000	360.000
TAP2	3	.000	.000	360.000
FLC1T	4	1.000	30.000	360.000
FLC2T	5	78.000	32.000	360.000
FLC3T	6	-37.000	17.000	360.000
FLC4T	7	42.000	31.000	360.000
P1H	8	1348.000	6.000	360.000
P1L	9	474.000	2.000	180.000
P2H	10	1184.000	7.000	180.000
P2L	11	462.000	2.000	360.000
P3H	12	971.000	6.000	180.000
P3L	13	253.000	2.000	360.000
DEL1	14	-.012	.016	359.820
DEL2	15	.000	.002	359.820
DEL3	16	-.001	.019	359.820
ACC1	17	-.030	.020	360.000
ACC2	18	.000	.020	360.000
ACC3	19	.000	.030	180.000
ACC4	20	.000	.010	360.000
ACC5	21	.000	.000	360.000
ACC6	22	-.010	.090	360.000
ACC7	23	.070	.000	360.000
ACC8	24	-.010	.050	360.000
ACC9	25	.010	.060	180.000
ACC10	26	.000	.020	360.000
ACC11	27	.000	.000	360.000
ACC12	28	.000	.020	360.000
ACC13	29	.000	.000	360.000

VIBRATORY LOAD LONGITUDINAL EXCITATION 500 LB FORCE 30HZ (RUN 6C)

PROCESSED DATA

EXTERNAL APPLIED LOADS AT A

V	34000.000	S	.000	D	.000	MX	.000	MY	.000	MZ	.000

CORRECTED ISOLATOR LOADS

FI1	9946.896	FI2	8073.122	FI3	8401.791

PROCESSED DATA

ACCELERATIONS:	X	Y	Z	ROLL	PITCH
UPPER PART OF UPPER BODY					
STEADY	-.010	.070	-.030	.000	-.000
VIBRATORY	.094	.001	.020	.138	.772
PHASE	-.000	-.000	360.000	180.000	-.000
LOWER PART OF UPPER BODY					
STEADY	.000	.000	-.030	.000	-.234
VIBRATORY	.020	.000	.020	.198	1.287
PHASE	-.000	180.000	360.000	180.000	-.000

INERTIA FORCES:	X	Y	Z	MX	MY
UPPER PART OF UPPER BODY					
STEADY	-48.080	336.560	-144.240	.000	.000
VIBRATORY	453.106	3.640	96.160	283.986	1831.184
PHASE	180.000	180.000	540.000	360.000	180.000
LOWER PART OF UPPER BODY					
STEADY	.036	.000	-90.141	.000	-463.200
VIBRATORY	59.894	.031	60.094	301.278	2547.600
PHASE	180.000	360.000	540.000	360.000	180.000

ISOLATOR LOADS:	NO.1	NO.2	NO.3
STEADY	9946.896	8073.122	8401.791
VIBRATORY	102.744	115.137	102.744
PHASE	-.000	180.000	180.000

OUTPUT

STEADY LOADS AT POINT A:	X	Y	Z
MEASURED	38.000	-36.000	26421.809
APPLIED	-.000	-.000	26187.300
ROTOR-MEASURED	38.000	-36.000	34234.509
ROTOR-APPLIED			

VIBRATORY ROTOR HEAD FORCES

	VERTICAL(Z)		LATERAL(Y)		LONGITUDINAL(X)	
	AMPLITUDE	PHASE	AMPLITUDE	PHASE	AMPLITUDE	PHASE
APPLIED	.000	.000	.000	.000	500.000	.000
MEASURED	41.117	-.000	2.610	-.000	526.000	-.000

****

LOADER CARD INPUT

```
COLUMN 2 4 6           19        31        43        55        67
       *   *           *         *         *         *         *
       *   *           *         *         *         *         *
       2   1   1       0
       2 109     750.0     10.0
       1 114      90.0
      -1 115       0.0
```

****

APPENDIX IV

Analysis of Contributions to Error in Measuring Vibratory Loads

The following is an analysis of three vibratory load conditions which substantiate the major contribution of acceleration measurements to the determination of vibratory loads.

1. Vertical Vibratory Load - 500 lbs. @ 30 Hz.

Isolator Vibratory Loads

#1 104.5 lbs.

#2 90.5 lbs.

#3 64.0 lbs.

Total 259.0 lbs.

Inertia Response of Transmission/Rotor Head

	Acceleration - g's	Force
Rotor Head	.06	288 lbs.
Transmission	.06	180 lbs.
	Total	468 lbs.

Total measured load = 727 lbs.

Accelerometer contribution to Total measured load = 468 lbs.

2. Vertical Vibratory Load - 495 lbs. @ 30 Hz.

Isolator Vibratory Loads

#1 -102 lbs.

#2 +102 lbs.

#3 -116 lbs.

Total -116 lbs.

Inertia Response of Transmission/Rotor Head

	Acceleration - g's	Force
Rotor Head	.06	288 lbs.
Transmission	.06	180 lbs.
	Total	468 lbs.

Total measured load = 352 lbs.

Accelerometer contribution to Total measured load = 468 lbs.

3. <u>Longitudinal Vibratory Load - 1000 lbs. @ 18.5 Hz.</u>

Loads present in Longitudinal Drag Links

Forward	+15 lbs.
Aft	-65 lbs.
Total	-50 lbs.

Inertia Response of Transmission/Rotor Head

	Acceleration - g's		Force
Rotor Head	.23		1105 lbs.
Transmission	.07		210 lbs.
		Total	1315 lbs.

Total measured load = 1270 lbs.

Accelerometer contribution to Total measured load = 1315 lbs.

Page Intentionally Left Blank

REFERENCES

1. Schmidt, S.A., Linden, A.W. etal. "Rotor Systems Research Aircraft - Predesign Study", Sikorsky Aircraft Report, SER-50775, prepared under Contract NAS1-11228, Sikorsky Aircraft Division, United Aircraft Corporation; for the National Aeronautics and Space Administration and the United States Army.

2. Von Hardenberg, P.W., and Saltanis, P.B., "Ground Test Evaluation of the Sikorsky Active Transmission Isolation System", USAAMRDL Report 71-38, Sikorsky Aircraft Division, United Aircraft Corporation; prepared under Contract DAAJ02-69-C-0101, September 1971.